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REVIEW

OF HYDROPOWER PLANTS INFLUENCE ON WATER QUANTITY AND QUALITY IN VENTA RIVER BASIN DISTRICTS

2017

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Abbreviation

a.s.l.	Above sea level;
BOD_5	Biological Oxygen Demand;
BQE	Biological Quality Elements;
CEN	Comité Européen de Normalisation (French: European Committee for Standardization);
DSFI	Danish Stream Fauna Index;
EQR	Ecological Quality Ratio;
HAP-LV	Hydromorphological Assessment Protocol of Latvia;
HMWB	Heavily Modified Water Body;
HPP	Hydropower Plant;
LEGMC	Latvian Environment, Geology and Meteorology Centre;
LFI	Lithuanian Fish Index;
LMI	Latvian National River Macroinvertebrate Index;
LRMI	Lithuanian River Macroinvertebrate Index;
LT	Lithuania;
LV	Latvia;
MIR	Latvian National River Macrophyte Index, modified version of Polish Macrophyte Index for Rivers;
MS	Meteorological Station;
RB	River Basin;
RBD	River Basin District;
RBMP	River Basin Management Plan;
RHI	River Hydromorphological Index;
UK	United Kingdom;
WB	Water Body;
WFD	Water Framework Directive;
WGS	Water Gauging Station

I. INTRODUCTION

River hydrological regime regulation can cause lower variability in flow and overall lower flow magnitudes in rivers downstream of dams. Low flows are associated with low oxygen level, temperature extremes, increased concentrations of contaminants and eutrophication. Dams also reduce connectivity along the river length, which has implications for nutrient and sediment transport, as well as it can have effect on downstream trophic structure and function.

River continuity is a vital part of healthy ecosystem and dry periods, caused by natural or man-made alterations and it may lead to irreparable damage of aquatic ecosystems. Fish fauna in particular is the most sensitive to hydrological alterations, mainly because of their inability to overcome artificial obstacles and getting to their feeding and spawning areas.

Determining how water ecological quality is affected downstream by dams and reservoirs is done through targeted habitat surveys and simulations by MESOHABSIM. Model can help set minimum environmental flow recommendations and determine biological indicators suitable and sensitive enough to assess hydromorphological pressure.

II. VENTA RIVER BASIN DISTRICT

Venta River Basin District (Venta RBD) consists of Venta, Bartuva and Šventoji river basins in Lithuania and of Venta as well as of small rivers basins entering both the Baltic Sea and Gulf of Riga including basins of Bārta and Irbe rivers in Latvia (Fig. 1). The total area of Venta RBD in Latvian territory is 15625.24 km^2, but in Lithuanian territory – 6277.3 km^2.

Geological structure of Venta RBD is shaped of two main parts - crystalline bedrock and the sedimentary cover dominated by Devonian age sedimentary rocks - dolomite, limestone, sandstone, clay and gypsum. A number of valuable features of present landscapes are situated in the basin such as ravines, boulders, waterfalls, caves and springs. As regards the soils in Venta RBD, they are mainly characterized by soils on sandy bedrock, the area in the southern part – by soils on clay, sandy loam and sandy clay bedrock as well. In the northern part of Venta RBD podzolic and peaty podzolic soils are typical, but in the middle part of the basin - sod podzolic soil and pseudo-gley soils as well as eroded podzolic soils at terrains and turf gley peaty soils in mires and low lying areas occur. At the coastal parts of Venta RBD in uplands a typical podzol on sandy bedrock is formed, but at the terrain depressions - peaty podzolicgley soils on the sand bedrock and sod gley soils are encountered [1].

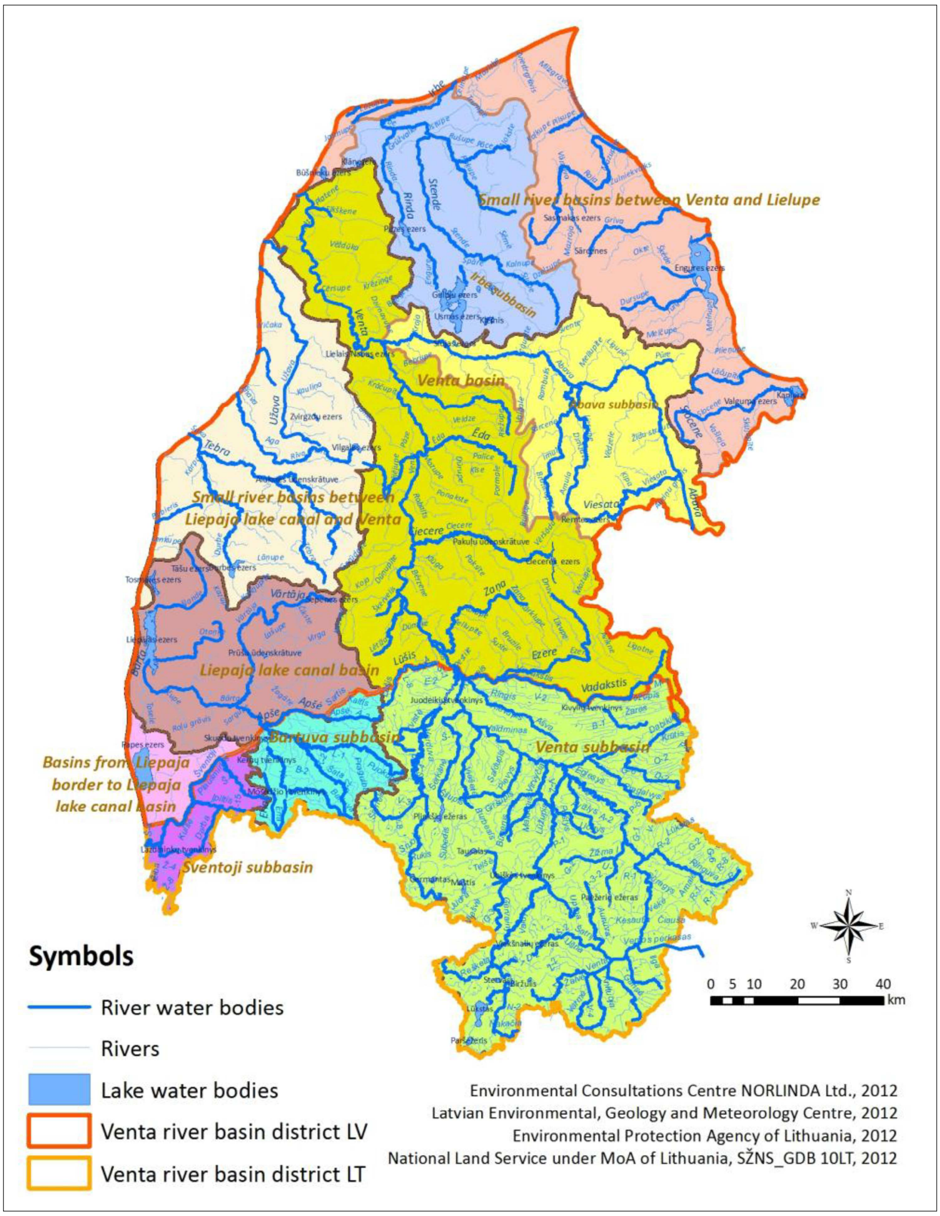

Figure 1. Venta River Basin District

2.1. TOPOGRAPHY AND HYDROGRAPHY OF VENTA RBD

2.1.1. Lithuania

Lithuanian part of Venta RBD is located in central and northern part of Samogitian Upland (Žemaičiai Upland) (Fig. 2). The central part of the Samogitian Upland consists of Middle Samogitian glaciodepression (alternative names: the Biržulis glaciodepression or the Germantas glaciodepression), which is surrounded by the Northern hilly massif in western part and the ice dividing massif, named Watershed (Takoskyrinis) in the eastern part. The altitude of Middle Samogitian glaciodepression reaches up to 160-180 meters above sea level (a.s.l.) [2]. The highest elevation in mentioned Watershed is found at altitude more than 200 meters a.s.l. where the highest point of Venta RBD, Šatrija Hill (228.7 meters a.s.l.) is located. The surface elevation of the Northern Samogitian Plateau fluctuates from 140 to 150 meters a.s.l. and landscape consists of small hills.

The sources of the Venta River and its biggest tributary – the Virvytė River are directly located in the centre of Samogitian Upland, where the Venta River rises from Lake Medainis and the Virvytė River begins in Lake Biržulis. The source of the Venta River is situated at Watershed and source of the Virvytė River is located at the Middle Samogitian glaciodepression. Further these rivers flow through Northern Samogitian Plateau, and at Middle Venta Plain the Virvytė River enters the Venta River.

In Lithuania, Venta RBD consists of the basins of Venta, Bartuva and Šventoji rivers. This district covers the area of 6 278.3 km². The largest part of this area depends to the Venta River basin (5 138.1 km²). The Bartuva River basin is the second largest basin (749.2 km^2). The Šventoji River basin occupies the 390 km^2. The sources of mentioned rivers are located in Lithuania.

The total length of the Venta River is 343.3 km and the catchment area consists of 11.8 thousands km^2. The Venta River flows 159.1 km in Lithuania, 1.7 km – at Lithuanian-Latvian border, and 182.5 km – through the territory of Latvia. There are only two larger tributaries: the Virvytė River (99.7 km) and the Varduva River (90.3 km) in Lithuania territory of Venta RBD.

The low-permeable soils are dominated in the Venta River Basin. The forests cover 28 % of this basin, while 7.3 % of territory is occupied by swamps and 1.5 % by lakes. The average slope of the Venta River is 0.085 %. The density of network of the rivers longer than 3 km is 0.68 km/km².

The total length of the Bartuva River is 101.3 km. Bartuva River flows 55.3 km in Lithuania and 46.0 km in Latvia territory. The low-permeable medium clay loams are dominated in the Bartuva River Basin. In Lithuanian part of this basin, forests cover only 3.2 %, swamps – 4.6 % and lakes – 0.2 %. The average bed slope of the Bartuva River is 0.26 %. The density of network of the rivers longer than 3 km is 0.66 km/km².

The length of the Šventoji River is 68.4 km. The river flows 19.9 km in Lithuania, 31.8 km – at Lithuanian-Latvian border, and 16.7 km – through the territory of Lithuania again. The slope of the Šventoji River varies from 0.14 % in the upper reaches to 0.004 % in the lower reaches (the average slope is 0.06 %). The 30.7 % of the basin is covered by forests, 4.2 % by swamps and only 0.3 % by lakes. The network density of the rivers longer than 3 km is 0.64 km/km² [3].

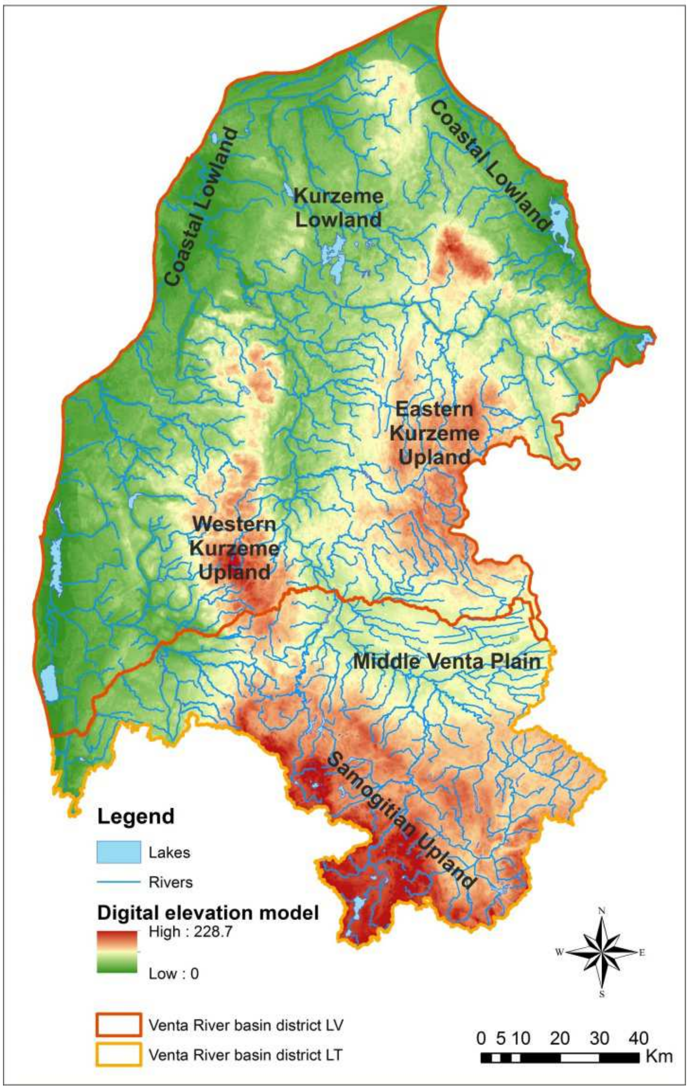

Figure 2. Topography and hydrography of Venta RBD

2.1.2. Latvia

Kurzeme upland is situated in central part of Venta RBD within Latvian territory. Venta River and Usma Lake valleys divide Kurzeme upland to western and eastern parts. Primary rocks are dolomite. River and lake valleys are cut across uplands, and are edged by moraine lines and forested continental dunes (Fig. 2). Percentage of forest in Venta RBD is 57 %, mares cover 2 % of territory but lakes only 1.5 %. More than 78 % of Venta RBD belongs to four large river basins – Venta (7900 km^2), Bārta (1280 km^2), Irbe (2000 km^2) and Saka (1110 km^2). There are only two rivers longer than 100 km (Venta and Abava rivers) and one lake (Usma Lake) larger than 10 km^2. River gradient is 7-8 m/km, river density varies from 0.20 km/ km^2 in the north to 0.50 km/ km^2 in the south.

2.2. CLIMATE AND HYDROLOGICAL REGIME

2.2.1. Lithuania

Lithuanian territory is located in the zone of temperate climate. Lithuanian climate can be characterized as a transitional between mild Western European and continental Eastern European climate. By the climate classification of B. Alisov, Lithuania belongs to the south-western part of the Atlantic continental forestation zone [4].

Venta RBD belongs to the Baltic Sea Basin. The sea has an impact on the change of meteorological factors and the hydrological regime of rivers. The influence of topography (Žemaičiai Upland) on these elements is significant as well.

Average annual air temperatures in Venta RBD are 6.0 ºC (Telšiai MS, 1924-2014) and 5.9 ºC (Laukuva MS, 1950-2014). Average air temperature of February (the coldest month of the year) is -4.3 °C, while average air temperature in July (the warmest month of the year) reaches 16.8 °C.

Amount of precipitation in Venta RBD varies from 600 mm/year for the Eastern part to 900 mm/year for the Western part of district. Average number of days with snow cover varies from 50 in the Western part to 90 in the Eastern part of Venta RBD.

Average annual number of days with snow cover in Venta RBD varies from less than 70 in the basins of the Šventoji River and Bartuva River to 90 in the Venta River basin.

The natural hydrological regime in the rivers of Venta RBD is characterised by spring flood, fall (autumn) and winter rainfall floods and summer drought (Fig. 3). In the rivers of Venta RBD spring runoff accounts for an average 34 %, summer – 12 %, and the fall-winter season – 54 % of the annual runoff. The frequent rains throughout fall and winter course flash floods, which sometimes reach runoff of spring flood or is even higher one (Fig. 3).

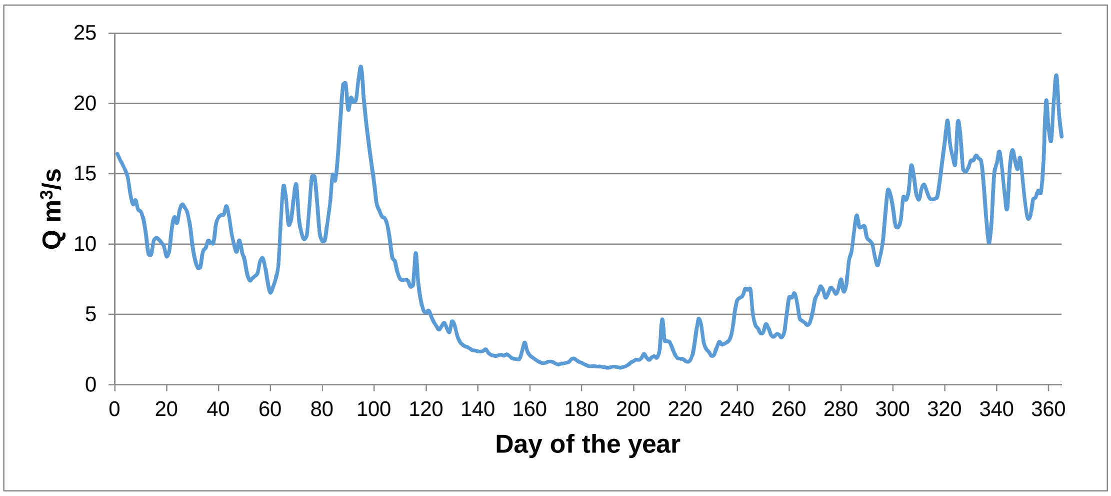

Figure 3. Hydrograph over multiple years (1972-1999) of the Bartuva River at Skuodas WGS before the construction of SHPs

Long-term annual water runoff in the rivers of Venta RBD is on average 8.4 l/sec·km², and it varies from 5.5 l/sec·km² in the Dabikinė River – Akmenė water gauging station (WGS) to 12.4 l/sec·km² in the Rešketa River – Gudeliai WGS (Table 1, Annex I).

Spring flood in the rivers of Venta RBD typically begins in the mid-March (from 14 to 19) and lasts 57 days in average – till late April. Average duration of spring flood is 39 days. It varies from 29 days (in the Aunuva River – Aunuvėnai WGS) to 47 days (in the Venta River – Leckava WGS). The part of spring flood in the annual water runoff is about 36 %.

The beginning of 30-day minimum flow period in Venta RBD was observed in July 20th (1942-1960) while since 1961 dry period becomes later - in August 10th. In 1942-1960 a dry period started in June 20th while from 1961 – in August 10th. The average runoff of the most dry 30-day summer period is from 0.42 $l/sec \cdot km^2$ (the Šventoji River – Večiai WGS) to 2.50 $l/sec \cdot km^2$ (the Rešketa River – Gudeliai WGS) (Table 1, Annex I).

The annual composition of river water feeding in Venta RBD is approximately 44-52 % rainfall water, 26-38 % snow melt water and 18-22 % groundwater.

The duration of ice cover in the rivers of Venta RBD varies in large scale. An initial ice cover forms in December and breaks up in May. However, over the last years the rivers of Venta RBD did not freeze annually. Some rivers freeze up only occasionally during periods of unusual cold winters.

2.2.2. Latvia

Polar Maritime air masses of the North Atlantic origin determine the climate properties in this region. Frequent thaws are observed during winter season and rains all around a year. In accordance with LEGMC long-term observations the monthly average air temperature for the period of 1961-2015 in the western part of Venta RBD is -2.2°C in February and 16.9°C in July, in the eastern part there is -3.8°C in February and 16.6°C in July. The annual air temperature of this period is 7.0°C in the western part and 6.0°C in the eastern. Annual amount of precipitation is 650-700mm and about 800 mm in Bārta RB. Average duration of snow cover is 65-75 days/year.

Hydrological regime is characterised by high spring flood, autumn and winter rainfall floods and summer drought (Fig. 4). Long-term annual water runoff is 8.0 l/sec*km^2 in average, and it is increasing to 13.0 l/sec*km^2 in Durbe RB.

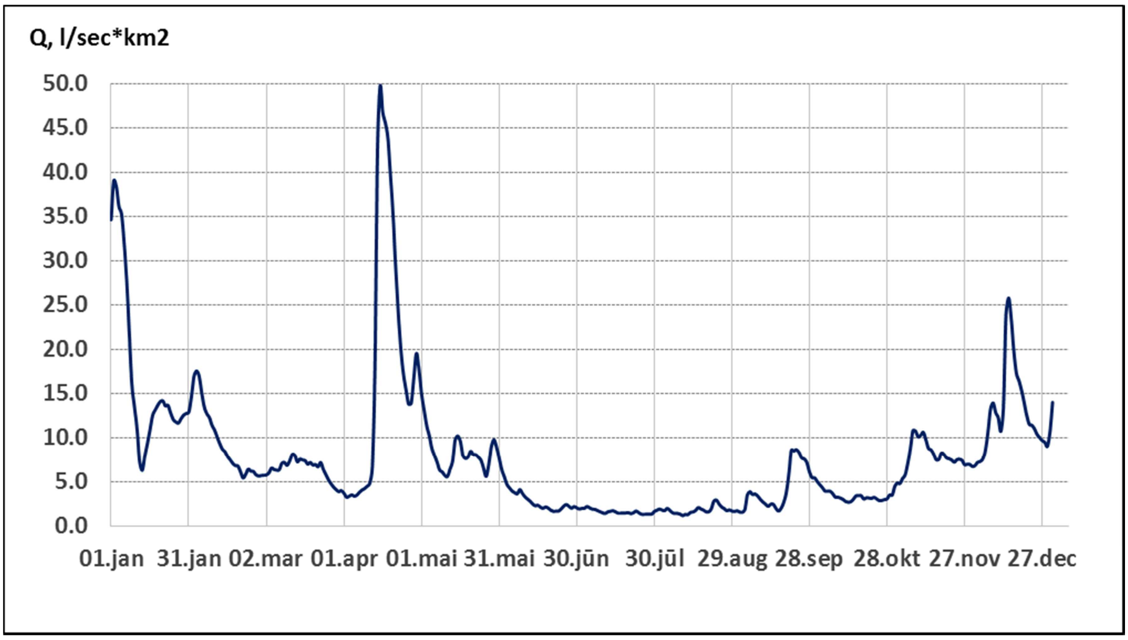

Figure 4. Hydrograph, the Venta River at Kuldīga, 2013

Spring flood start in the end of first decade of March and lasts 57 days in average – till mid-May. The part of spring flood in the annual water runoff is about 30 %. Usually it is combined - snow melting and rainfall waters.

30-days low flow period usually is observed from the end of second decade of July untill the end of first decade of August. The average water runoff at that periods is less than 2.0 l/sec*km^2. The main hydrological characteristics of rivers estimated using long-term observations are displayed in Annex I (Table 2).

The part of groundwater in the annual water runoff is less than 10 %, and 60 % belong to rain waters.

First ice phenomena on rivers appear in the first decade of December, and in the beginning of January rivers freeze up. However in 19 % of winter ice cover does not form (90 % for the Durbe River). Ice cover break-up is observed in the end of first decade of March but ice phenomena period lasts till mid-March.

2.3. RIVER HYDRO-MORPHOLOGY, PRESSURES AND CLASSIFICATION

2.3.1. Lithuania

The main hydromorphological parameters of Venta RBD are presented in Table 1. According to available data, the average depth of the Venta River is 1.1 m, Virvytė and Vadakstis – 0.7 m and Varduva – 0.6 m. The average width of the Venta River is 20.2 m, Vadakstis – 14.6 m, Virvytė – 14.4 m and Varduva – 12.9 m.

Table 1. Hydromorphological parameters of Venta RBD within Lithuanian territory

Catchment	River	Distance from the mouth, km	Segment length, km	Slope, ‰	Average depth, m	Average width, m
Venta	Vadakstis	26.2	10.2	0.451	0.6	13.9
	Vadakstis	17.5	8.7	0.356	0.7	14.8
	Vadakstis	8.4	9.1	0.516	0.7	15.4
	Vadakstis	0.0	8.4	1.357	0.7	14.1
	Varduva	50.8	19.3	0.964	0.5	11.6
	Varduva	35.2	16.6	1.229	0.5	11.4
	Varduva	23.4	11.8	0.941	0.5	12.2
	Varduva	16.7	6.7	0.597	0.6	14.0
	Varduva	9.5	7.2	0.500	0.7	15.2
	Varduva	0.0	9.5	1.295	0.6	12.8
	Venta	194.9	6.2	0.613	1.4	23.6
	Venta	315.5	4.0	0.600	0.5	12.0
	Venta	276.2	2.8	0.464	0.8	16.5
	Venta	275.3	0.9	0.556	0.8	16.9
	Venta	269.0	6.3	0.889	0.8	15.5
	Venta	245.4	20.6	1.010	0.8	15.8
	Venta	236.3	9.1	0.549	0.9	17.9
	Venta	229.4	6.9	0.478	1.0	18.9
	Venta	224.0	5.4	0.389	1.1	21.3
	Venta	219.4	4.6	0.130	1.8	31.1
	Venta	201.1	18.3	0.339	1.5	26.0
	Venta	185.5	9.4	0.383	1.6	26.7
	Virvytė	83.4	14.1	0.546	0.6	13.4
	Virvytė	62.1	21.3	1.404	0.5	11.3
	Virvytė	50.3	11.8	0.924	0.6	12.8
	Virvytė	45.5	4.8	0.729	0.7	14.0
	Virvytė	39.4	6.1	0.836	0.8	15.4
	Virvytė	5.0	34.4	1.044	0.8	15.2
	Virvytė	0.0	5.0	0.400	1.0	18.8
Bartuva	Apšė	0.0	4.2	0.643	0.6	13.1
	Luoba	0.0	6.0	0.750	0.6	12.7
	Bartuva	52.0	9.7	0.567	0.5	12.2
	Bartuva	47.0	5.0	1.440	0.6	12.1

The Bartuva River is more shallow and narrow: the average depth is 0.6 m and width – only 12.5 m. The slopes of different river segments in the basins of the Venta and Bartuva range from 0.13 to 1.44 ‰ (Table 1).

Lithuanian rivers are classified into 5 types according to two main criteria: catchment area and a slope of the riverbed (Table 2) [5].

Table 2. Typology of rivers in Venta RBD (by Venta RBMP, 2015)

Factors	**Type**				
	1	**2**	**3**	**4**	**5**
Absolute height, m	<200				
Geological	Calcareous				
Catchment area, km^2	<100	100–1000		>1000	
Bed slope, m/km	–	<0.7	>0.7	<0.3	>0.3

Environmental Protection Agency (EPA) of the Republic of Lithuania grouped rivers of Venta RBD according to the river typology presented in Table 2. As can be seen from Table 3 and Figure 5, water bodies of all five types can be found in Lithuanian part of Venta RBD. Water bodies of types 1 and 3 dominate in the basins of the rivers Venta, Bartuva and Šventoji. Water bodies of types 4 and 5 are characteristic only for Venta Basin, since these water bodies must have the catchment area of at least 1000 km^2 according to the typology (Table 3).

Table 3. Number and length of river water bodies of different types in Venta RBD (by Venta RBMP, 2015)

Type	**Venta Basin**		**Bartuva Basin**		**Šventoji Basin**		**Venta RBD**	
	Number of water bodies	**Length of water bodies, km**	**Number of water bodies**	**Length of water bodies, km**	**Number of water bodies**	**Length of water bodies, km**	**Number of water bodies**	**Length of water bodies, km**
1	56	474.3	6	84.1	2	10.7	64	569.1
2	7	102.9	1	34.1	3	80.3	11	217.3
3	11	189.4	4	77.3	1	4.1	16	270.8
4	2	23.5	0	0	0	0	2	23.5
5	2	95.8	0	0	0	0	2	95.8
Total	**78**	**885.9**	**11**	**195.5**	**6**	**95.1**	**95**	**1176.5**

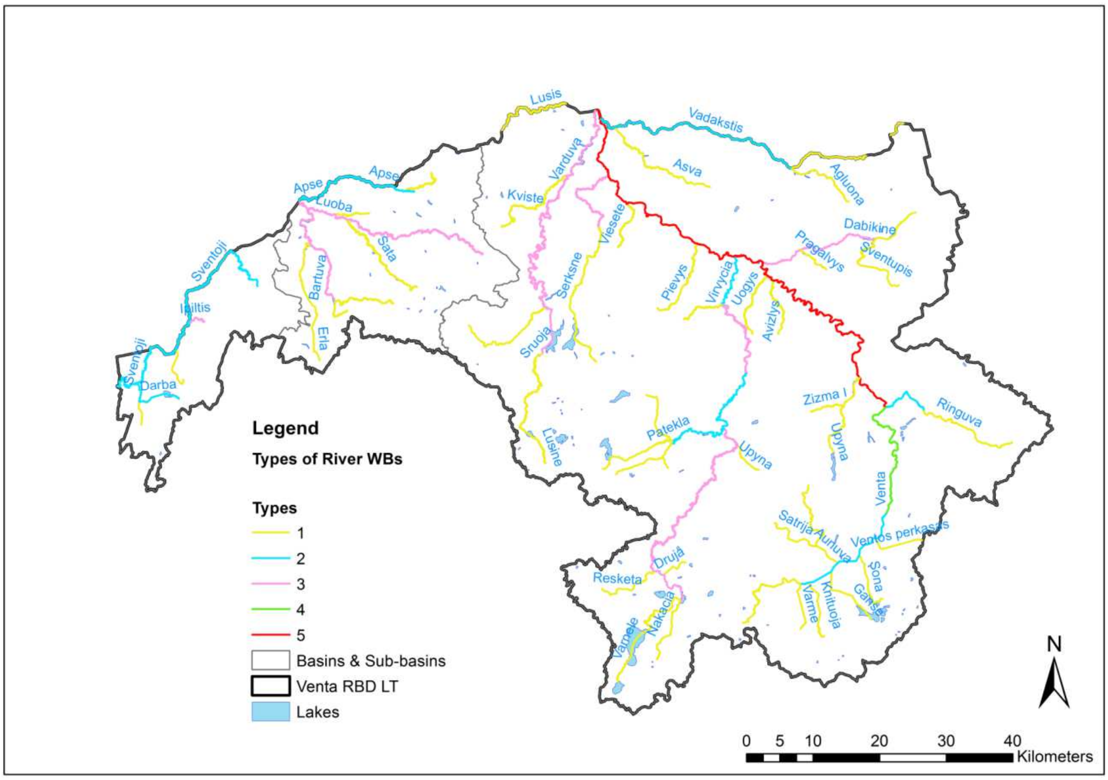

Figure 5. Types of river water bodies in Venta RBD (prepared according to Lithuanian EPA data)

Ecological status of Lithuanian rivers is evaluated according to the hydromorphological quality elements: hydrological regime (water discharge and dynamics), river continuity and morphological conditions (bank and riverbed structure; runoff amount and character; condition of riparian vegetation; soil composition). River ecological status is expressed by the river hydro-morphological index (RHMI). There are three classes of hydro-morphological quality state: very good, good, and worse than good (Table 4). RHMI is calculated according to methodology approved by Lithuanian Minister of Environment [6]. The studies of evaluation of RHMI for Venta River basin district have not been fully completed; therefore, the results are not yet published.

Table 4. Classes of river ecological status based on the hydrological regime, river continuity and morphological conditions (by Venta RBMP, 2010)

<table>
<tr><th colspan="3" rowspan="2">Quality element</th><th rowspan="2">Index</th><th rowspan="2">River type</th><th colspan="3">River ecological status according to hydromorphological criteria</th></tr>
<tr><th>Very good</th><th>Good</th><th>Worse than good</th></tr>
<tr><td>Hydrological regime</td><td>Water runoff volume and dynamics</td><td>Runoff amount and character</td><td rowspan="5">RHMI</td><td rowspan="5">1-5</td><td rowspan="5">1.00-0.91</td><td rowspan="5">0.90-0.80</td><td rowspan="5"><0.80</td></tr>
<tr><td colspan="3">River Continuity</td></tr>
<tr><td rowspan="3">Morpho-logical conditions</td><td rowspan="3">Bank and riverbed structure</td><td>Character of the riverbed</td></tr>
<tr><td>Condition of riparian vegetation</td></tr>
<tr><td>Soil composition</td></tr>
</table>

Identification of main pressures within Lithuanian territory: hydropower impact. The negative effects of HPP dams on ecosystem are: disruption of the continuity of the river, altering natural flow fluctuations, altering water quality and modifying channel morphology, as well as bed structure by increasing siltation upstream and erosion downstream.

Hydropower dams damage the ecological integrity and stability of river ecosystem. They block fish migration from lower river reaches to the upper ones. The blocked movement of fishes together with changed habitat and physicochemical conditions of streams may be the reason of decreased number of fish species, converting lotic habitats to lentic, etc.

Altered natural water level regime changes the whole hydrological regime of a river downstream. Especially high water level fluctuations (i.e. hydropeaking) occur downstream from the HPPs, which are operating only a few hours per day. Upstream from the impoundment, river floodplain is usually flooded and, as a consequence, river bank erosion begins.

Rivers in Venta RBD are significantly influenced by their high hydropower generation capacity. There are 30 HPPs in this river basin district (Fig. 8). More detailed information on HPPs in Venta RBD is presented in Table 4 (Annex I). The area of the reservoirs of five HPPs is larger than > 0.5 km^2 (classified as HMWB due to their large area; the characteristics of such reservoirs are more similar to lakes than to rivers).The largest number of HPPs has been constructed on the Virvytė River. Since these HPPs are located at a small distance from each other, they are deemed to be exerting a significant impact on the river water even though their reservoirs are smaller than 0.5 km^2 (almost the entire Virvytė River has been designated as a HMWB due to the impact of HPPs). River water bodies, which are assigned to a risk group due to impact of HPP, are given in Figure 6.

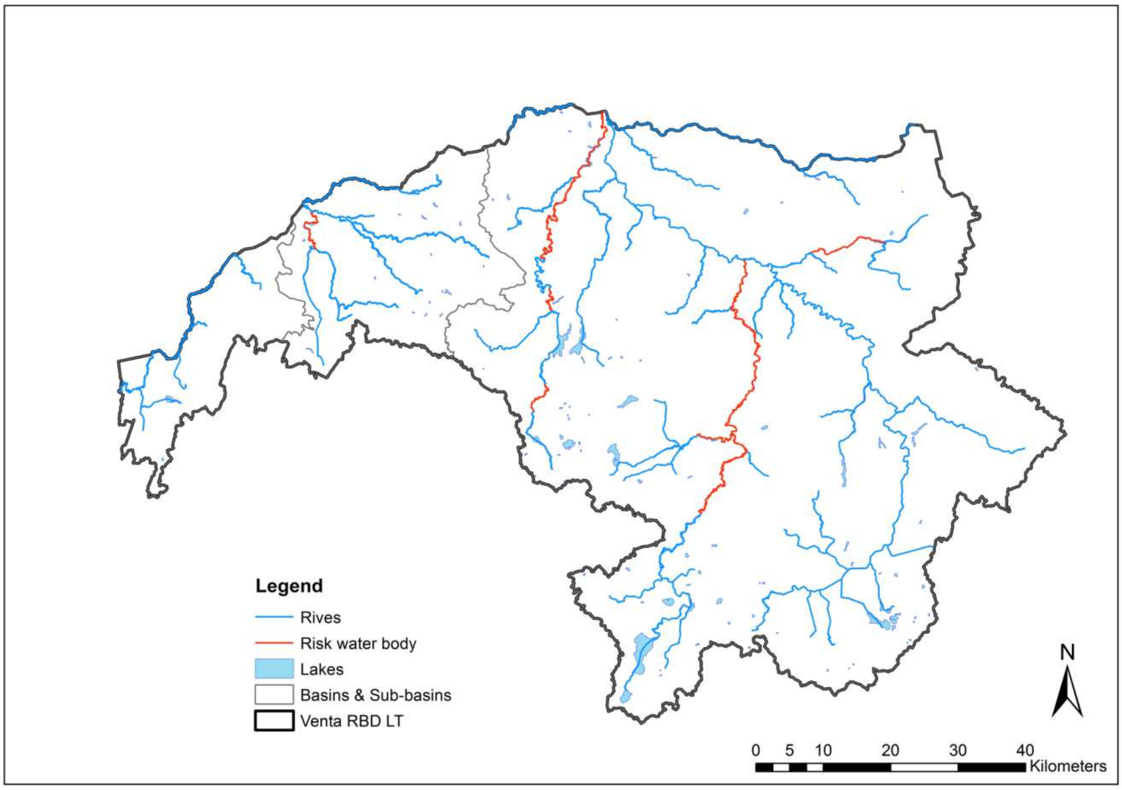

Figure 6. Water bodies, assigned to a risk group due to impact of HPP within Lithuanian territory

Identification of main pressures within Lithuanian territory: significant impact of river straightening. Riverbed regulation results in morphological changes, which are assessed using the criterion K3:

$$K_3 = \frac{\sum L_{reg}}{L_u}$$

where ΣL_{reg} is the aggregated length of regulated river stretches, km; L_u is the total length of the river.

When $K_3 \leq 20$ %, morphological changes in the riverbed are minimal, and anthropogenic transformations do not have any significant impact thereon. When this value is exceeded by up to 10 %, morphological changes are assumed to be small; when up to 30 % – changes are medium; when 30-100 % – changes are significant; and when the value is exceeded by more than 100 % – morphological changes are considered to be very significant. The length of river stretches designated as HMWB and water bodies at risk due to a significant impact of straightening is given in Table 5 and Figure 8.

Table 5. Length of river stretches and number of water bodies due to significant impact of straightening (by Venta RBMP, 2015)

Catchment	Number of straightened water bodies	Number of rivers designated as HMWB due to straightening	Number of rivers designated as WB at risk due to straightening	Length of rivers designated as WB at risk due to straightening, km
Šventoji	2	0	2	10.7
Bartuva	1	1	0	0
Venta	35	29	6	31.6
Total in Venta RBD	**38**	**30**	**8**	**42.3**

Identification of main pressures within Lithuanian territory: drainage reclamation. The purpose of drainage reclamation is to regulate the moisture regime of the soil thus providing favourable conditions for plants. Lithuania is situated in the zone of surplus humidity therefore ditches were dug and drainage systems were constructed to remove this surplus from cultivated land. Reclaimed areas in Venta RBD are given in Table 6.

Table 6. Reclaimed areas in Venta RBD (by Venta RBMP, 2015)

Basin	Total reclaimed area, ha	Drained area, ha	Share of the total reclaimed area in the basin area, %
Šventoji	25 912.12	17 853.05	54.9
Bartuva	52 715.62	50 081.24	70.4
Venta	25 527.07	244 153.04	49.6

Systematised information on river hydromorphology and the main pressures is necessary in further study, when case studies from Lithuanian part will be selected for more detailed investigation.

2.3.2. Latvia

The types of rivers in Latvia and in Venta RBD as well have been specified, using System B of the European Community. Size of the catchment area and mean water slope are used as the main factors in rivers typology.

According to the height above sea level (<200 m), geographical longitude and latitude all river water bodies of Venta RBD have been divided in one class, because significant ecological differences between rivers have not been observed in Latvia due to such indicators.

Riverbeds in Venta RBD are mainly of carbonatic origin, therefore, one class – rivers with carbonate bed – has been singled out in typology.

Rivers in Latvia are classified into 6 types according to two main criteria: catchment area and mean water slope [7] (Tab.7).

In accordance with RBMP 2-d cycle, there are 4 river water bodies classified as the first type, 2 - as the second type, 22 - as the third type, 21 - as the fourth type, 1 - as the fifth type and 11 - as the sixth type in Venta RBD within Latvian territory (Fig. 7).

Table 7. Typology of rivers in Latvia

No.	Catchment area	Mean water slope	Type	Characterisation of the type
1.1.	Small (< 100 km^2)	Large (> 1.0 m/km)	Small ritral-type river	The river is shallow, the speed of the current exceeds 0.2 m/s. The substrate of the bed is formed by sand and gravel
1.2.	Small (< 100 km^2)	Small (< 1.0 m/km)	Small potamal-type river	The river is shallow, the speed of the current is less than 0.2 m/s. The substrate of the bed is formed by sand covered in detritus of organic origin and silt
1.3.	Medium large (100–1000 km^2)	Large (> 1.0 m/km)	Medium ritral-type river	The river is medium deep, the speed of the current exceeds 0.2 m/s. The substrate of the bed is formed by boulders, cobbles, sand and gravel
1.4.	Medium large (100–1000 km^2)	Small (< 1.0 m/km)	Medium potamal-type river	The river is medium deep, the speed of the current is less than 0.2 m/s. The substrate of the bed is formed by gravel, sand covered in detritus of organic origin and silt
1.5.	Large (> 1000 km^2)	Large (> 1.0 m/km)	Large ritral-type river	The river is deep, the speed of the current exceeds 0.2 m/s. The substrate of the bed is formed by sand, gravel and rocks
1.6.	Large (> 1000 km^2)	Small (< 1.0 m/km)	Large potamal-type river	The river is deep, the speed of the current is less than 0.2 m/s. The substrate of the bed is formed by sand covered in detritus of organic origin and silt

The types, number and length of water bodies in largest river basins Venta, Saka, Bārta and Irbe are given in Table 8. It is evident, that small rivers of 1st and 2nd types were not designated at all in those basins. However, some of small tributaries of main rivers are regulated by HPPs. The revision of existing water bodies is in progress now.

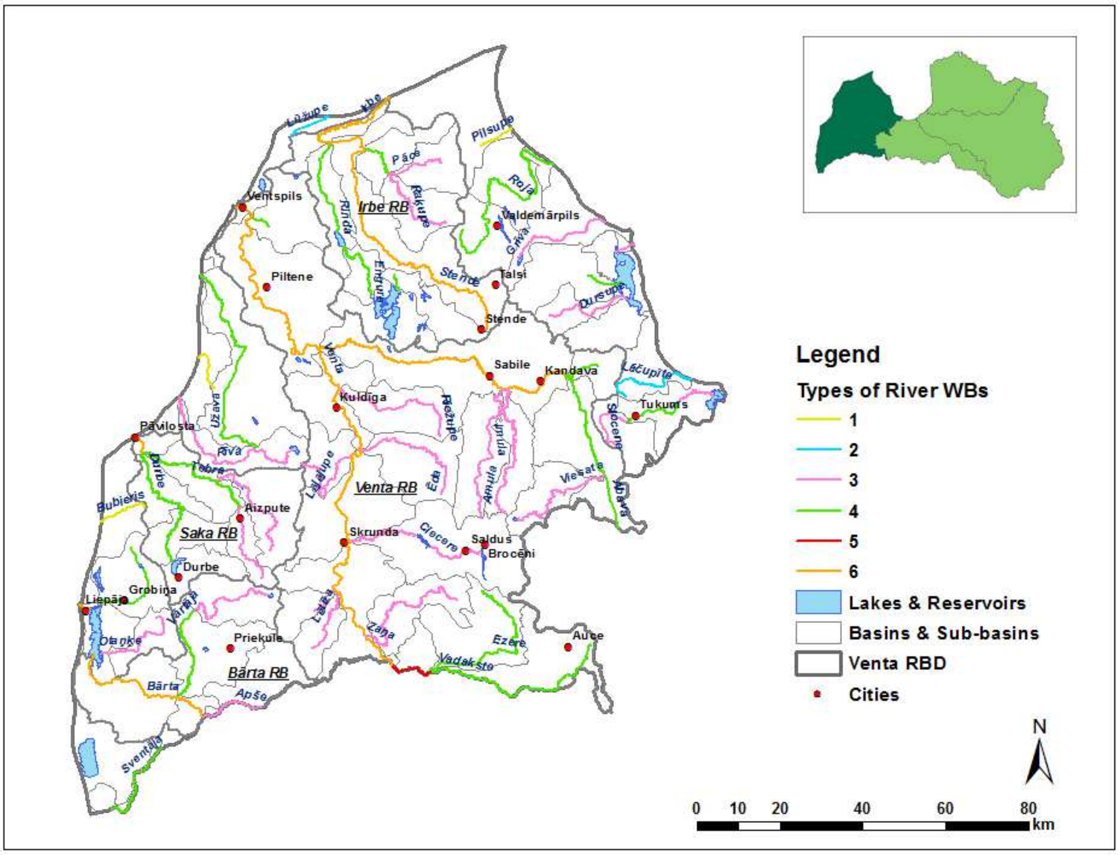

Figure 7. Types of river water bodies in Venta RBD within Latvian territory (by Venta RBMP, 2015)

Hydro-morphological monitoring in Latvia and in Venta RBD started in 2013. Until year 2017 morphological, river continuity and hydrological conditions have been surveyed in 32 river water bodies from 62 designated in Venta RBD. For the rest hydro-morphological quality assessment has been done by expert judgment using land and water use information as well as historical hydrological data.

Table 8. Number and length of river water bodies of different types for large rivers of Venta RBD

Type	Venta Basin		Bārta Basin		Saka Basin		Irbe Basin	
	Number of water bodies	Length of water bodies, km	Number of water bodies	Length of water bodies, km	Number of water bodies	Length of water bodies, km	Number of water bodies	Length of water bodies, km
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	10	411.5	2	76.0	2	82.2	2	70.1
4	5	177.2	1	34.2	3	108.8	4	77.6
5	1	13.0	0	0	0	0	0	0
6	6	266.5	2	46.8	1	6.7	2	128.5
Total	**22**	**868.2**	**5**	**157.0**	**6**	**197.7**	**8**	**276.2**

6 water bodies are located in the river mouth stretches and designed as heavily modified due to multiple uses in seaports (5) and due to significant morphological changes (1).

HAP-LV method on the base of Hydromorphological Protocol of Slovak Republic is used for the assessment of WB's hydromorphological quality. This method covers three main components: hydrological regime, river continuity and river morphology.

Two first components will be described below in item 2.4. River morphology is assessed by 4 groups of parameters, where each is targeting different aspects of the morphological structure of the river or stream:

- Channel plan form parameters (channel sinuosity, channel type and channel shortening);
- In-stream parameters (river bed elements, bed substrates, variation in river width, flow types, large woody debris and artificial bed features);
- Bank and riparian zone structures (riparian vegetation, bank stabilization and bank profile);
- Floodplain structure (flooded area and natural vegetation).

All parameters are assessed with scores from 1 (natural or near-natural conditions) to 5 (severely modified conditions). For each group of parameters the average score is calculated. Finally the worse score determines the Hydromorphological quality of a water body.

As a monitoring result 4 main hydromorphological pressures in Venta RBD (Fig. 8) were identified:

- River drainage and water regulations (deepening of river bed, shortening of changing of bank profile);
- Hydropower Plants (barrier to fish and sediment migration, hydrological regime regulation);
- Polders (flood protected dams, water pumping);
- Multiple morphological pressures (seaports location in river mouth stretches).

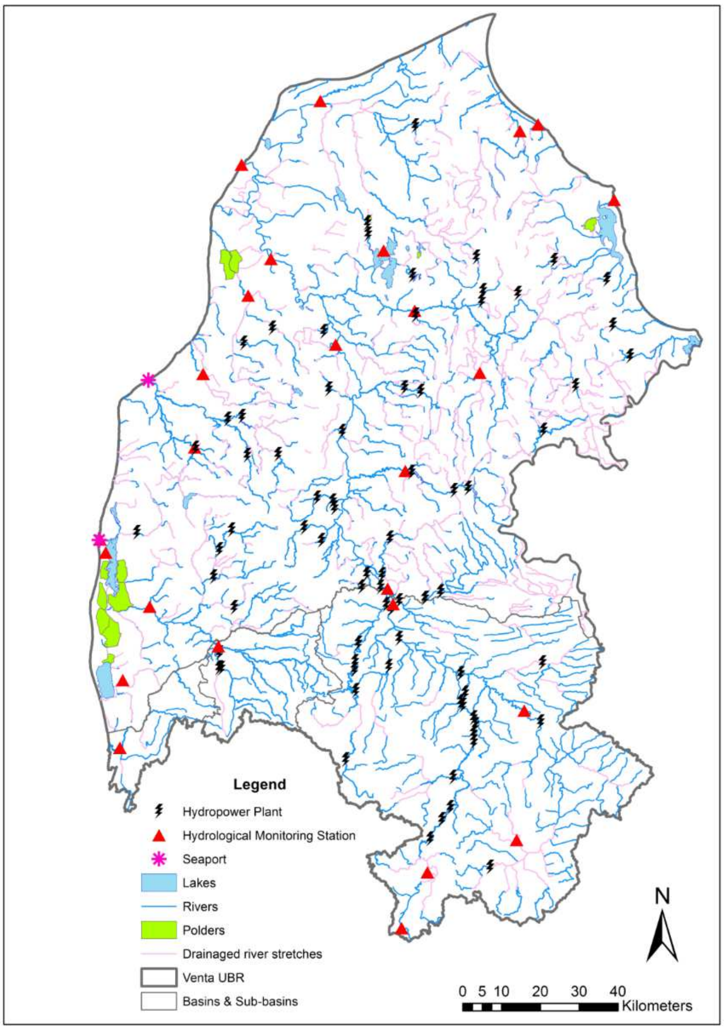

Figure 8. Main hydromorphological pressures in Venta RBD

Water body quality class depending on anthropogenic pressures is shown in Table 9, detailed information is in Annex I (Table. 3).

Table 9. Hydromorphological quality of water bodies in Venta RBD

Quality (class)	Identified anthropogenic pressures	Number of water bodies
5	Seaports (multiple use)	5
	Polders with area >10% of water body basin area	1
4	Length of drained stretches >75% of water body'' length	4
	2-3 HPPs along a water body	7
	Multiple pressures	8
3	Length of drained stretches >50% of water body'' length	4
	HPPs on small tributaries	2
	1 HPP but impact is not significant	2
	Significant morphological changes	3
2	Slight morphological changes	6
	Drained stretches on tributaries	2
1	No pressures, reference conditions	16

2.4. ASSESSMENT OF INFLUENCE OF HYDROPOWER PLANTS ON WATER QUANTITY

2.4.1. Lithuania

Development of hydro-energy is associated with Renewable Energy Directive and Water Framework Directive (WFD) for European waters. Though hydropower is renewable energy, construction and operation of HPPs have negative impact on river ecology: river connectivity disruption (changes of hydrological regime), impact of flow regulation on biological elements (minimum flows, hydropeaking), and modifications of sediment transport. Hydropower dams alter natural flow regime and harms riverine ecosystems.

Different characteristics of flow regime can be affected by the hydropower dams: annual, maximal and low flow, intra-year distribution of river runoff, water level fluctuations, etc.

30 small hydropower plants were constructed on the rivers of Venta RBD. These HPPs are located on 10 rivers (Table 4, Annex I). Even 11 small hydropower plants were constructed in the Virvytė River (left tributary of the Venta River). Meanwhile, streamflow in this river was monitored only ten years (1954-1963), before the construction of HPPs. Currently streamflow is monitored only in 2 rivers (3 WGS) where the HPPs are constructed.

Many small HPPs are operated with little water storage capacity relative to the volume of flow in the river, resulting in only minor alterations to flow regimes. However, larger hydropower dams with considerable reservoir storage capacity are able to capture high water flows and store them for later use. This can result in substantially lowered flood peaks downstream hydropower dam (Fig. 9).

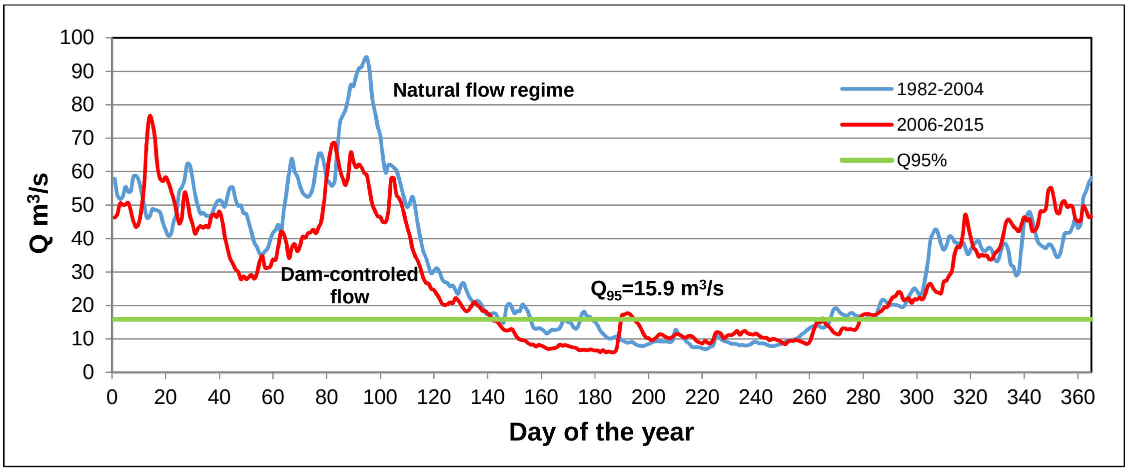

Figure 9. Hydrographs of Venta River – Leckava WGS (downstream of Kuodžiai HPP) for the natural flow period (1982-2004) and dam-controlled flow (2006-2015)

Fig. 9 shows that stream flow in the first half of the year have a tendency to decrease after the construction of HPP. In the second half of the year, natural flow and dam-controlled flow were usually changeable.

2.4.2. Latvia

48 hydropower plants are located in 28 water bodies but on 38 rivers (Table. 5, Annex I). Ten regulated rivers are not designated as a separated water bodies, and HM monitoring on these rivers is not carried out.

Two components of HAP-LV are used for the assessment of HPPs impact on water quantity and quality – “river continuity” parameter and “hydrological regime” group of parameters.

River continuity parameter shows the impact of barriers on fish and sediment migration along the river. In presence of barriers in streams, this parameter is critical for the assessment of the water body hydromorphological quality. Guidance standard on determining the degree of modification of river hydromorphology is used for the assessment of this quality element (Table. 10).

Table 10. Classification of River Continuity (Water quality - Guidance standard on determining the degree of modification on river hydromorphology [8])

High class (near-natural)	Good class (slightly modified)	Moderate class (moderately modified)	Poor class (extensively modified)	Bad class (severely modified)
Continuity of the river is not disturbed by human activities (any dams).	Artificial structures are present, but having only minor effects on migration of aquatic organisms and sediment transport.	Artificial structures are present, but having moderate effects on migration of aquatic organisms and sediment transport (dam has a fish pass).	Artificial structures having a great effect on migration of aquatic organisms and sediment transport (few species are able to pass a dam, but almost all sediment is retained behind a dam).	Artificial structures are having a great effect on migration of aquatic organisms and sediment transport (all sediment is retained behind a dam, or presence a large dam with height of 15 m or with height from 5 to 15 m and a reservoir capacity of more than 3 mil m^3).

Hydrological regime parameters are used to evaluate the effect of artificial impacts on the hydrological regime in the sampling site and indirectly on aquatic ecosystem. The hydrological quality is assessed by 4 parameters:

- change in mean flow,
- change in low flow,
- change in water level range,
- impact of artificial frequent flow fluctuations.

Figure 10 shows Durbe River water level fluctuations compared to Riva River water level over 3 months period. These fluctuations of Durbe River flow are related to operations of Ciecere HPP that is located on the Cepuļupe River - tributary of Durbe River, 330 m upstream of monitoring station.

An impact of only 3 small HPPs on hydrological regime can be determined by analysing of hydrological data due to limited number of hydrological monitoring stations in Venta RBD (Fig. 8). Therefore expert judgment, partly on the base of existing long-term hydrological observations, is used for the assessment of HPP impact on water quantity. This impact is the most significant in case when 2 or 3 hydropower plants are operated in one water body.

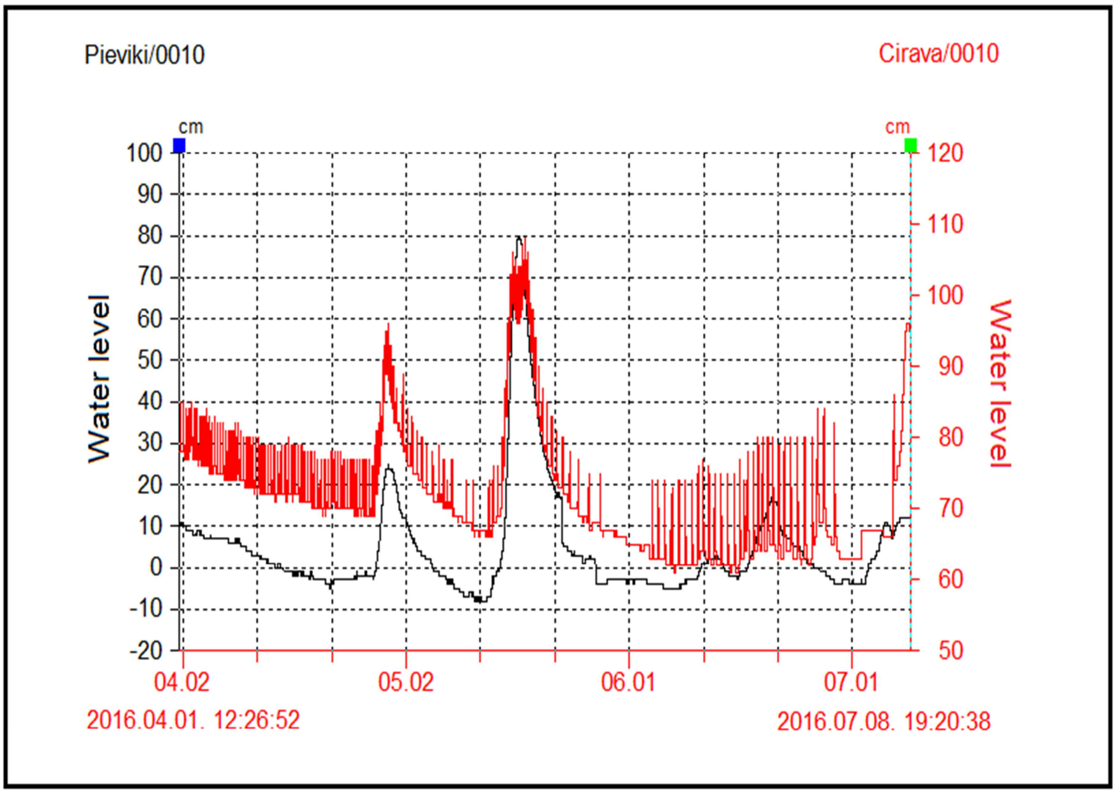

Figure 10. Durbe River water level downstream Cirava HPP (in red) vs Riva River water level at Pieviķi (in black).

Ciecere River long-term hydrograph downstream 3 HPPs (Fig. 11) shows not only the picking but extended low flow period as well.

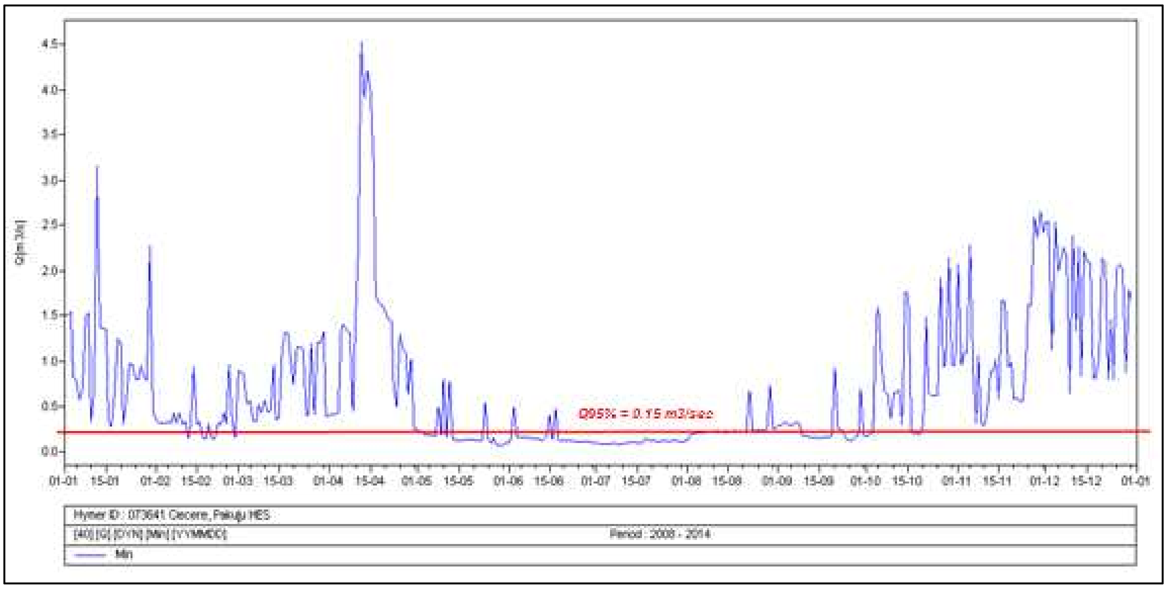

Figure 11. Hydrograph of Ciecere River downstream of HPP Pakuli for period 2008-2014 in compare with water discharge of 95% probability

However, existing monitoring does not allow to estimate the influence of HPP on aquatic ecosystem.

2.5. RELATIONSHIPS BETWEEN BIOLOGICAL QUALITY AND MORPHOLOCICAL ALTERATIONS

2.5.1. Lithuania

Macroinvertebrates and fish metrics are commonly used for assessment of deviations in river water quality and hydromorphological conditions. Lithuanian River Macroinvertebrate Index (LRMI) and Lithuanian Fish Index (LFI) are officially approved methods for assessment of ecological status of rivers in Lithuania [9]. These indices integrate the most sensitive to environmental perturbations macroinvertebrate and fish metrics, and characterize the ecological status of rivers by assessing deviation of metrics values from reference conditions. Similarly, for assessment of river hydromorphological status, the River Hydromorphological Index (RHI) has also been developed in Lithuania. RHI covers specific hydrological and morphological metrics and assesses their deviation in comparison with undisturbed conditions. [9] Descriptions of LRMI, LFI and RHI methods are given in Annex II. Thus, assessment of relationships between biological quality and hydromorphological conditions can be conducted by analysing relationship between biological indices and RHI.

Impact of hydromophological perturbations on aquatic community status can be correctly assessed only in case that there are no other significant pressures (e.g. pollution). In addition, data on fish and macroinvertebrate metrics at reference conditions should also be present as a basis for assessing the deviation. Due to intense economic activities, reference status river sites are absent in Venta RBD. There are only few river sites at good ecological status, too [3]. Venta RBD borders Nemunas RBD, so they are geographically close. There are no substantial differences in climatic or hydrological characteristics that could lead to very specific natural characteristics of the rivers (and hence in the structure and composition of aquatic communities). The impact of changes in river hydromorphology on LRMI and LFI was analysed in all studied sites in Venta RBD. A representative database was created, covering the entire range of hydro-morphological conditions in the rivers meeting high or good ecological status according to water quality criteria. Database consists of 178 river sites where the river hydrology and/or morphology were the only drivers of macroinvertebrates and fish communities.

Methods. Dependence of fish and macroinvertebrate based indices values upon river hydromorphological status (RHI scores) were assessed by the means of regression analysis. ANOVA and Tukey post-hoc test were applied for significance of differences of LRMI and LFI scores in the river sites of different status class according to RHI. Significance of differences of LRMI and LFI scores were also tested by grouping river sites based on scores of different hydrological and morphological metrics, covered by RHI. For the latter purpose, analysing indices response to single hydromorphological metric, river sites that did not meet requirements for at least good status according to other hydromorphological metrics and water quality criteria were eliminated from analysis. For instance, only those sites were selected for analysis of response to river channel modifications, which met requirements for good status according to criteria of hydrological regime, substrate composition, and riparian vegetation as well as water quality criteria. Such grouping allowed assessment of LRMI and LFI response to a particular hydrological or morphological perturbation and thus avoiding potential side effect of other pressures.

Results. Both fish-based and macroinvertebrate-based indices correlate with the scores of RHI (Fig. 12). Coefficient of determination in LFI and RHI relationship is rather high (R^2 = 0.64; $P < 0.001$); thus river hydromorphological characteristics have a significant impact on fish community status. LFI values significantly differ in the river sites of different status class according to RHI ($P < 0.01$). Gap in LFI values is the largest between 2 and 3 status class (Fig. 13). In case of significant disturbance of river hydromorphology (RHI status class > 2), LFI values correspond only to bad ecological status class (LFI < 0.40; see Annex II). LFI differs significantly between different status classes derived based on separate metrics of RHI, too (Fig. 14). Therefore, fish are sensitive to hydromorphological disturbances of various types.

Relationship between macroinvertebrates (LRMI) and RHI is also significant (0.344; $P < 0.001$); however, coefficient of determination (R^2 = 0.12) is much lower in comparison with relationship between RHI and fish. There is no difference in LRMI values between river sites of RHI status class 1 and 2; in case of moderate disturbance of river hydromorphology (RHI status class 3), LRMI values still correspond to criteria of good ecological status (Fig. 13). LRMI is quite sensitive to changes in composition of bottom substrate, and to significant changes in the hydrological regime; however, an impact of other hydromorphological perturbations on macroinvertebrates is negligible (Fig. 14).

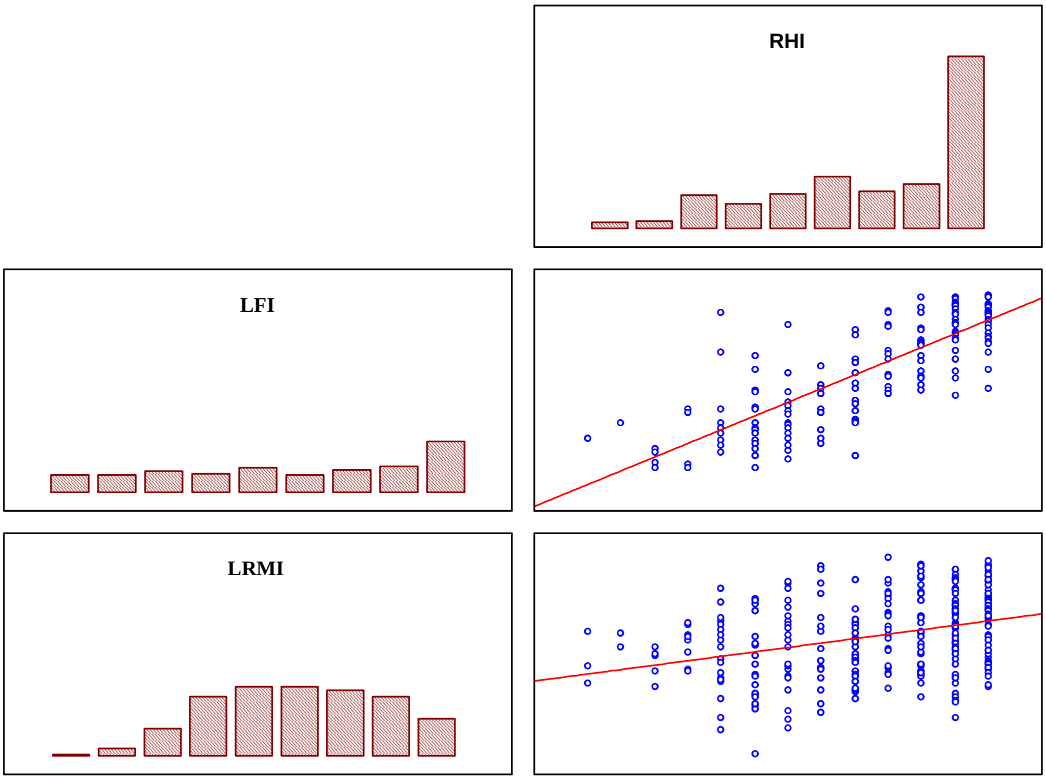

Figure 12. Relationship between biological indices and RHI

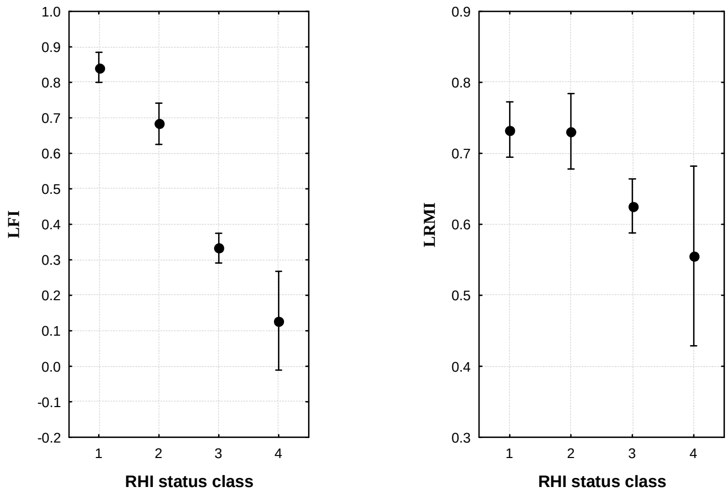

Figure 13. LFI and LRMI values (mean ± SD) in the river sites of different hydromorphological status class according to RHI.

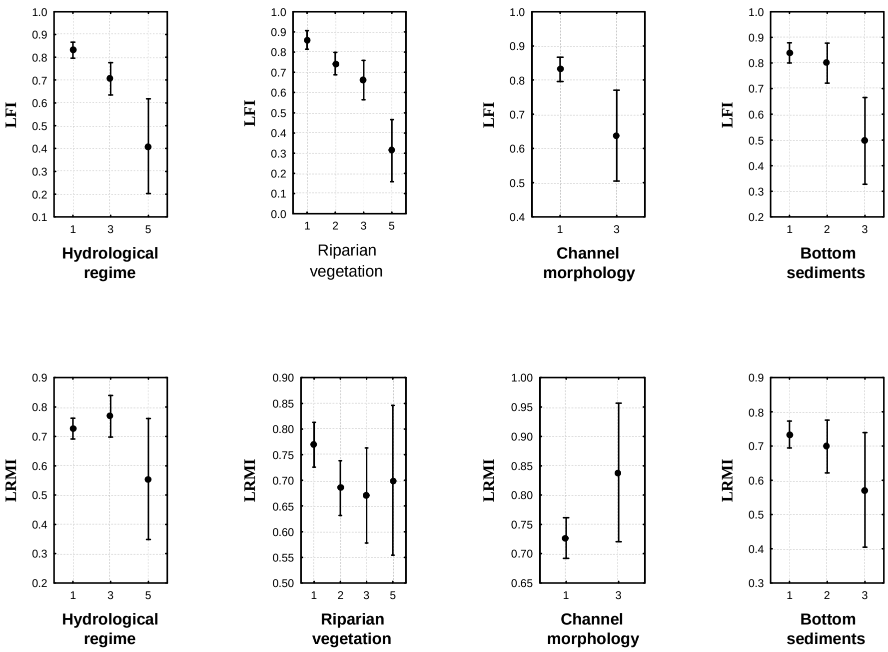

Figure 14. LFI and LRMI values (mean ± SD) in the river sites differing in the scores of RHI metrics

These results indicate that fish are much more sensitive to river hydrological and morphological changes than macroinvertebrates. Macroinvertebrate metrics respond only to significant perturbations of river hydromorphology.

2.5.2. Latvia

With aquatic habitats we understand in-stream composition of macrophytes and bed substrate which creates suitable environment for different aquatic organisms. Hydrological regime is the main force which determines aquatic habitat structure and its suitability for different life stages of flora and fauna.

Benthic macroinvertebrates and macrophytes were used to detect links between hydromorphological alterations caused by hydropower plants and biological quality elements. Both, macroinvertebrate and macrophyte indices, were calculated according to newly intercalibrated methods (available at https://circabc.europa.eu/webdav/CircaBC/env/wfd/Library/working_groups/ecological_status/). Other biological quality elements (BQE) were not available.

Besides national macroinvertebrate index LMI and its subindices (Average Score Per Taxa, Danish Stream Fauna Index), Lotic-invertebrate Index for Flow Evaluation LIFE [10], in Guidance Document No. 31 [11] mentioned as potentially suitable and to be developed method, was tested for Latvian streams. LIFE score, developed in UK, was used to estimate how hydrological pressure affects benthic macroinvertebrates. This index is based on division of macroinvertebrate families into one of six flow groups. Each flow group is associated with different flow requirements: I (rapid flows), II (moderate to fast flows), III (slow to sluggish flows), IV (slow flowing and standing waters), V (standing waters) and VI (drought impacted sites). This index can be easily calculated using historical data and are good and inexpensive option to assess influence of flow alterations.

Macrophytes were also tested on how they respond to hydrological alterations. Newly developed Latvian MIR index and number of plant species were used as response indicators. As plant abundance was expressed in nine-point scale, it was not possible to calculate other indices.

It is very challenging to assess hydromorphological degradation impact on biological communities, because existing monitoring system haven't been developed to assess such impact. Most of surface water biological and hydrochemical monitoring stations are located in river mouths or in other stretches relatively far from hydroelectric power plants (Fig. 15).

In total, hydrological pressure can be linked to 39 streams in Venta RBD (50 HPP). It must be noted, that some of these hydroelectric stations, that significantly affects flow regime, are located in Lithuania, close to LT-LV border. For example, HPP on the Sventāja River at Radomišķi/Laukžeme (Lithuania) affects not only Lithuanian side but Latvian side of river as well. Water level fluctuations caused by HPP on Bārta River at Skuodas affects downstream reaches in Latvia.

Surface water and biological monitoring station network covers only 18 rivers with operating hydroelectric power plants which can possibly affect 21 biological monitoring stations. Other HPP are on rivers which were not designed as water bodies and therefore no monitoring has been done. Only 7 monitoring stations are located up to 5 km from nearest HPP where biological response can be measured. For 8 monitoring stations biological response to HPP was impossible to assess, because they are located more than 10 km from hydroelectric power plant which limits response intensity. Due to HPP impoundments, natural streams have lost their natural floodplain and riparian habitats. Although some investigations have found that flow fluctuations caused by HPP can affect stream even up to 27 km downstream, biological response can be found only in samples are collected maximum 5-7 km from HPP (Tab. 11). It must be taken into account that biological response to HPP vary between river types (size and stream velocity).

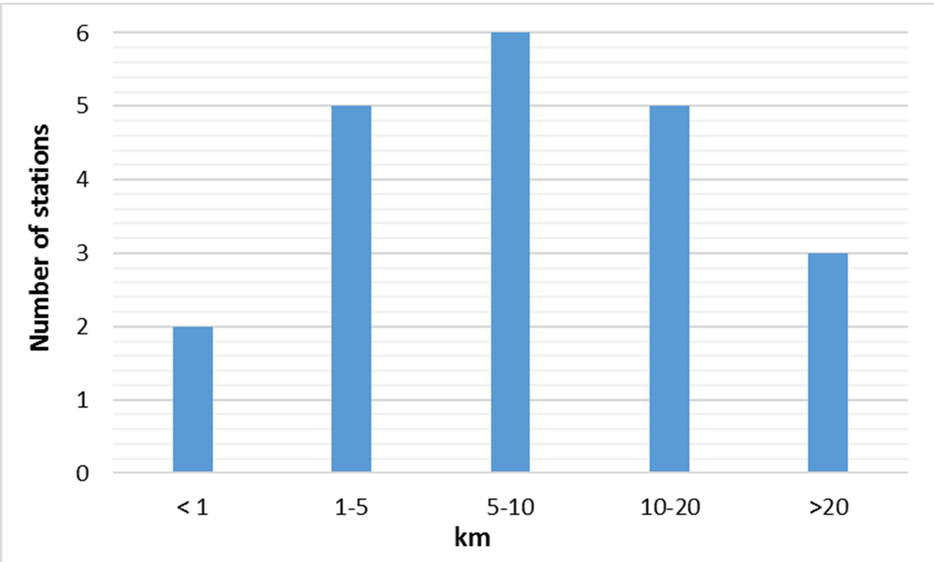

Figure 15. Distance between monitoring stations and HPP in Venta RBD (when HPP was located between two monitoring stations, smallest distance was taken into account)

From all biological indices (in particularly macroinvertebrates), DSFI was best linked to hydrological modifications. Although developed to assess organic pollution, it can be used also to assess general degradation. As it can be seen in Figure 16, hydrological alterations due to HPP cannot be directly linked to water quality deterioration in river water bodies. One of the reasons is that surface water quality monitoring sites in most cases are located very far from HPP and it's not possible to estimate possible effect. Also, multiple pressure co-existence limits availability to assess only hydrological alterations. Exceptions are rivers Sventāja, Latvian-Lithuanian boundary and Ālande, mouth where DSFI indicated worse quality class than physico-chemical assessment. Bārta River, which in Latvian part is impacted by HPP in upstream part (Lithuania) and polders in downstream reaches, do not show any response to hydromorphological alterations, probably because monitoring station is located too far.

Comparison of LIFE scores before and after year 2001 on rivers Alokste and Ezere are shown in Table 11. Invertebrate samples in both periods were collected almost in the same place. After HPP renovation on Alokste River amount of moderate to fast flows preferable species (LIFE group II) have decreased from 77.4 % to 18.5 %, but amount of slow flowing and standing waters preferable species (LIFE group IV) have increased from 9.5 % to 44.2 %. New HPP was built on Ezere River (and other one was renewed) in year 2001. Amount of moderate to fast flows preferable species (LIFE group II) have decreased from 55.2 % to 9.7 %. Number of slow flowing and standing waters preferable species (LIFE group IV) have not significantly increased, probably because of effect of already established HPP dam upstream. For both rivers also amount of rapid flows preferable species (LIFE group I) gave decreased after renovation of HPP which could be explained with decrease of riffles caused by impoundments.

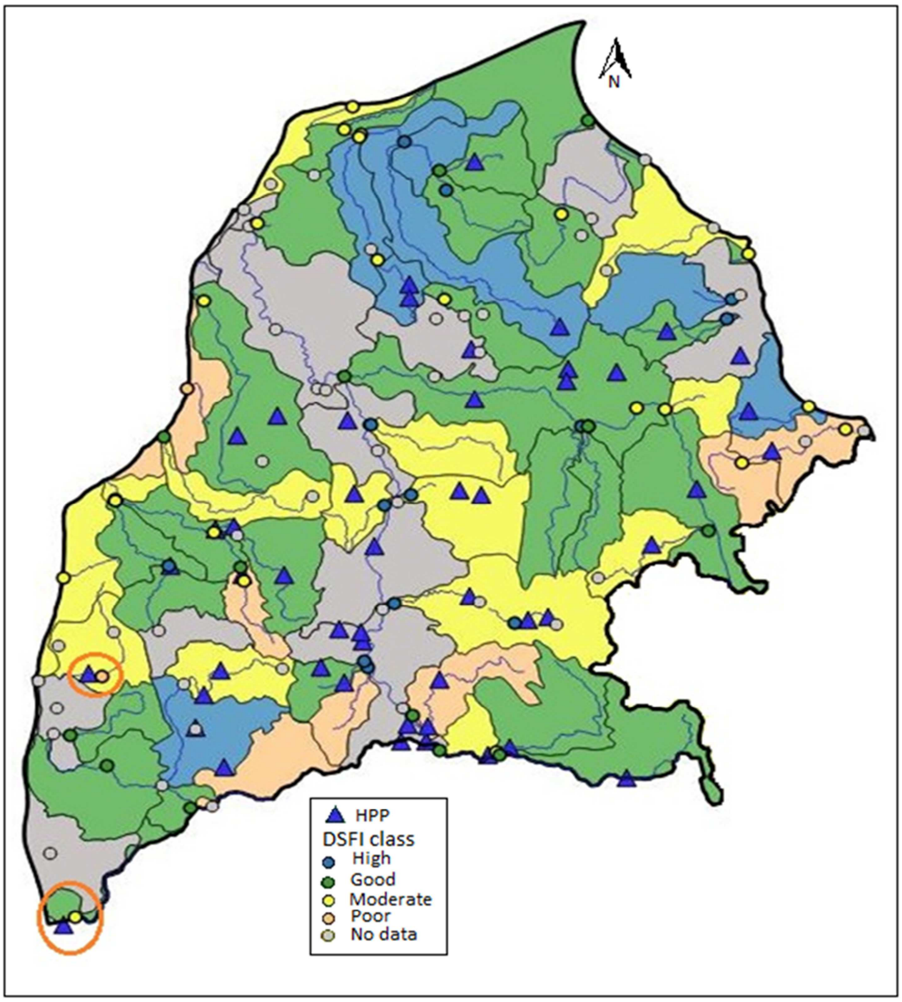

Figure 16. Surface water biological and hydrochemical quality in Venta RBD (triangles - HPP, dots - monitoring stations, catchments and MS are colored according to their chemical and biological (DSFI) quality class)

Table 11. Comparison of LIFE scores in rivers Alokste and Ezere before and after HPP renewal

LIFE group	Year	Alokste, grīva	Ezere, grīva
I	1998-2001	1.19	4.8
	>2006	0.43	0.0
II	1998-2001	77.38	55.2
	>2006	18.45	9.7
III	1998-2001	0.00	0.0
	>2006	1.64	0.0
IV	1998-2001	9.52	34.9
	>2006	44.21	35.3
Comments		HPP renewed in 2001	new HPP in 2001

As it can be seen in Table 12, in rivers without any hydrological alterations distribution of fast and slow flowing invertebrate species are relatively similar. If monitoring station is located downstream from HPP, amount of fast flow loving species (LIFE groups I and II) are decreased from 1.35 % to 0.03 % (I) and 32.71 to 17.2 % (II) compared to rivers with no hydrological alterations.

Table 12. LIFE score (percentage of macroinvertebrate species) distribution in sites with various hydrological impact in Venta RBD

HPP location	I	II	III	IV	V
No HPP	1.18	32.71	1.82	36.78	0.04
< 5/7 km	0.96	24.21	1.00	43.16	0.05
> 5/7 km	1.35	35.51	1.84	34.55	0.19
Downstream from MS	0.03	17.17	1.48	44.19	0.03

Fast flow preferable species are more suitable indicators of flow alterations than slow flowing LIFE flow groups (Fig. 17). Taxa primarily associated with slow flows showed great variability even in sites with no hydrological alterations, most likely because of large number of potamal rivers included in these analysis.

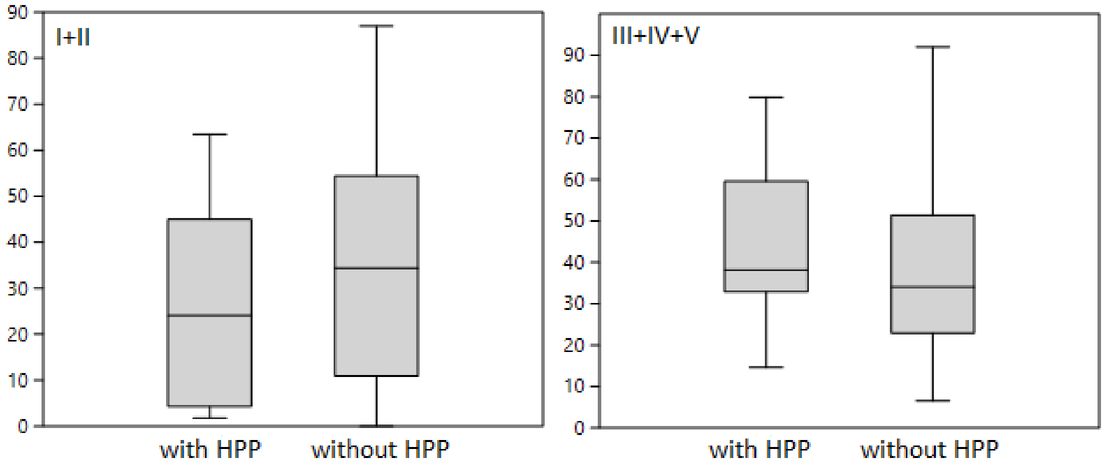

Figure 17. LIFE score distribution (percentage) in sites with and without hydroelectric power plants in Venta RBD

River ecological quality, assessed using macrophyte and benthic macroinvertebrate indices included in routine monitoring, showed different results

(Fig. 18 and 19). Macrophytes (Latvian MIR index) revealed no clear differences between stream sites with or without HPP, in hydrologically impacted streams mean MIR values were even higher. Also, number of plant species did not show any response to HPP. Rivers with monitoring station above HPP had higher mean MIR index values than sites with HPP located below (Fig. 18). It could be explained with slower velocity and higher nutrient content in impounded river stretch. Substance accumulation processes together with decreased flow and substrate accumulation may create suitable conditions for macrophyte overgrowth also downstream of dam, which is not representative for natural, freely flowing streams. Benthic macroinvertebrates (national LMI index) were significantly higher in sites without any HPP (Fig. 19), but it must be interpretive with caution because LMI EQR values are very low and in most cases indicates moderate/poor state even in undisturbed river stretches.

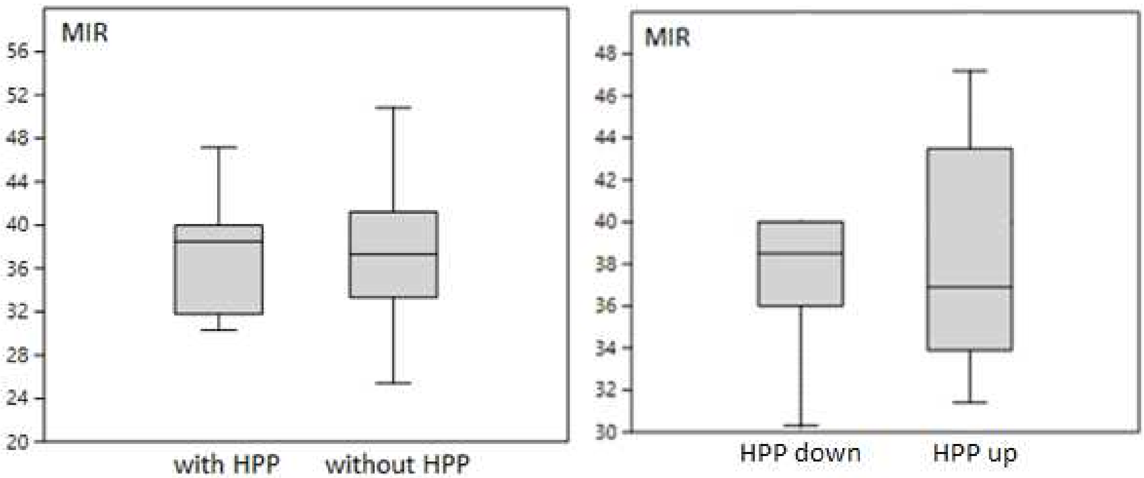

Figure 18. The variation of macrophyte (MIR) index (left) and with HPP located above and below biological monitoring site in studied streams in Venta RBD

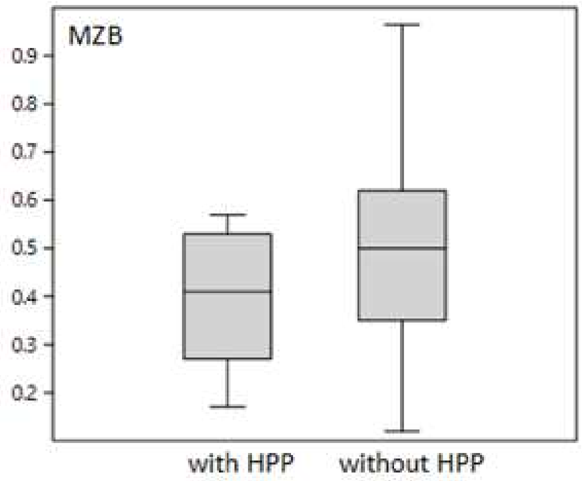

Figure 19. The variation of national macroinvertebrate (mzb) index in studied streams with and without HPP in Venta RBD

Mean oxygen saturation in rivers with HPP impact was about 0.8 mg O_2/L lower than in rivers without hydrological impact. Slow flowing rivers (natural or due to damming) have lower self-purification which causes deterioration of chemical quality. It is very challenging to link effects of HPP with changes in hydrochemical composition of rivers. In Venta RBD it was not possible to find a river that was affected only by hydrological pressure and usually also point and diffuse pollution, land use and morphological changes also significantly affects river stretch. Mean values of BOD_5 were significantly higher in rivers with presence of HPP, also P_{tot} revealed greater concentration (Fig. 20). Substance concentrations usually are higher above dam, because in lentic conditions substances start to accumulate. But once again, increased concentrations of hydrochemical substances cannot be explained only with effect of water level fluctuations or impoundments.

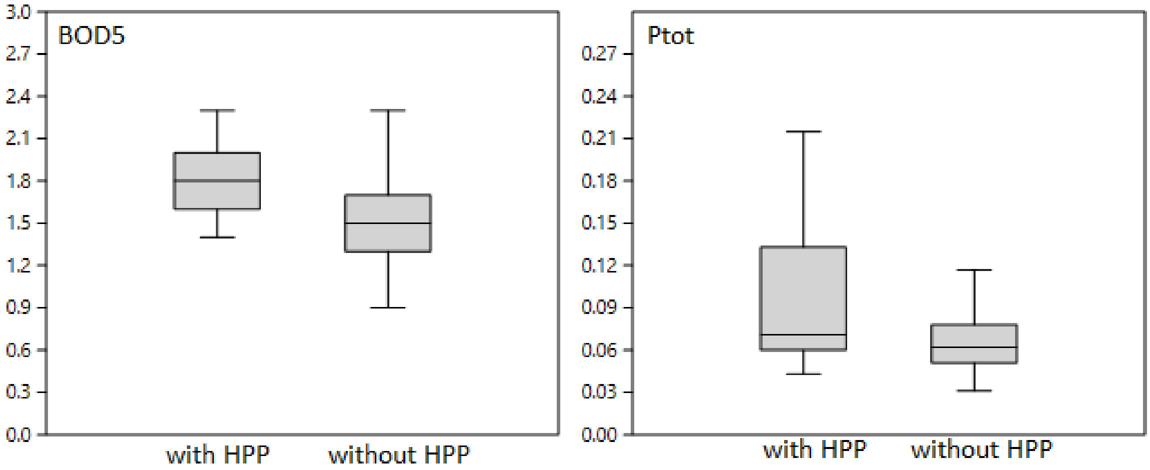

Figure 20. Variation of BOD_5 and P_{tot} in streams with different hydrological pressure intensity in Venta RBD

HPPs as migratory barriers. About 45% of river water bodies within Venta RBD belong to fast flowing rithral rivers and most of HPPs are located in upland areas in rivers with great slope. Hydropower plants have significant impact on fish communities, because upstream or downstream dams are artificial obstacles, that interrupt natural migratory routes and several fish species can't reach their feeding and breeding sites. In total, about 26.7 % of Venta RBD are inaccessible for migratory fish due to currently operating HPP (Fig. 21). As no fish passes are installed, it makes insurmountable obstacle. When former mill ponds (with or without sluice) are taken into account, about 31 % of Venta RBD are inaccessible for migratory fishes. Almost all larger catchments are impacted by connectivity barriers. Exceptions are smaller catchments in coastal plain which are naturally slow flowing and therefore are unsuitable for energy production. Artificial impoundment with barrier can be found also on Amula River, close to its mouth, but it does not have significant impact on ecological status. Lithuanian part of catchments was not included in this analysis. It must be noted that this map is only theoretical and river continuity disruption must be checked by experienced ichthyologists.

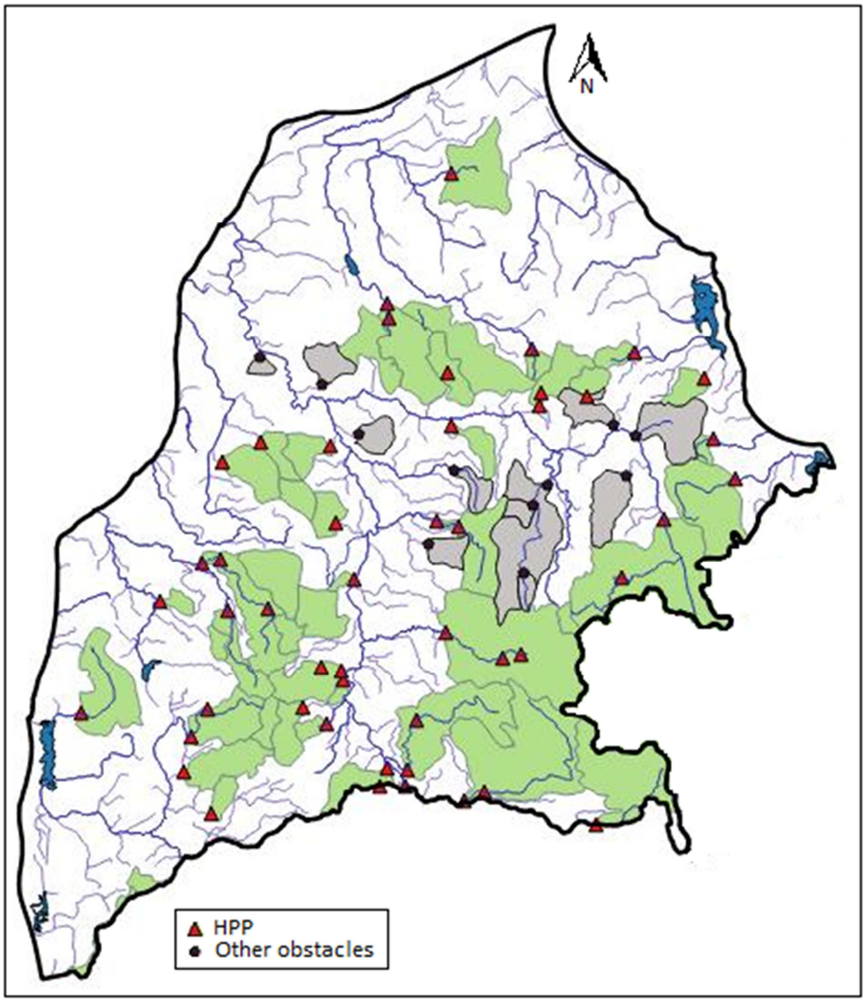

Figure 21. Areas inaccessible for migratory fishes in Venta RBD due to operating HPPs (green catchments) and other artificial obstacles (grey)

III. CONCLUSIONS

Changes of river hydrological regime caused by operating HPPs are significant pressure within both LT and LV parts of Venta RBD. Currently and formerly exploited HPPs significantly impact fish migratory routes and about 31 % of Venta RBD is inaccessible for migratory fishes.

However, only one study “Evaluation of small HPP operation” on small hydropower plants impact has been done by “Vides Projekti” in 2004-2005. The Report of this study states that the total loss of aquatic ecosystem affected by HPPs “…not to be calculated because the impact can be found after a long period of time“ [12]. Nowadays HPP impact is more evident but degradation of river ecosystems still hasn’t been estimated.

Biological quality elements and their indices used in routine monitoring are not sensitive enough to assess habitat degradation. Biological quality metrics (macrophytes, macroinvertebrates), used in the current State surface monitoring programme for assessment of the eutrophication, are not susceptible to any kind of hydromorphological alterations. LIFE index, described in this review, clearly shows that benthic macroinvertebrates are strongly affected by flow modifications.

Obviously, more attention must be paid to hydromorphological pressure assessment.

The meso-scale habitat model (MesoHABSIM) can provide solutions in sense of biodiversity protection by using multivariate statistics to predict fish species distribution and to define habitat suitability criteria. Specifically, these techniques can be used for selecting ecologically effective restoration measures and for establishing ecological flow criteria at hydropower or water withdrawals [13].

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ANNEX I

Table 1. Hydrological parameters in the rivers in Venta RBD within Lithuanian territory

No	River	WGS	Opened	Closed	Distance from the mouth, km	Drainage area, km^2	Period of record	Average discharge (Q), m³/s			30-day minimum discharge (Qmin 30), m³/s			Lowest daily discharge during the period of record, m³/s
								Multi-year average	Module, l/(s·km²)	Q95%	Multi-year average	Module, l/(s·km²)	Q95%	
1	Venta	Ramučiai	1963	1987	308.2	695.8	1963 – 1987	4.73	6.7	2.35	0.84	1.19	0.36	0.21
2	Venta	Papilė	1933-02-01 1947-08-17	-	252.1	1560	1947 – 2015	9.93	6.4	5.02	1.70	1.08	0.74	0.43
3	Venta	Kuodžiai Leckava	1939-11-07 1982-09-28	-	188.8 186.2	4021.1 4024.2	1949 – 1983 1983 – 2015	29.1	7.6	15.9	5.19	1.28	2.05	0.96
4	Aunuva	Aunuvėnai	1973-11-01 2006-10-17	-	4.8	94.0	1974 – 2015	0.56	6.8	0.26	0.071	0.63	0.015	0.008
5	Ringuva	Gedinčiai	1952 1962	1956 1966	2.5	31.,6	1952 – 1956, 1962 – 1966	1.68	5.7		0.11	-	-	0.035
6	Dabikinė	Akmenė *(Papilė)*	1956	1976	10.2	295.5	1956 – 1976	1.43	5.5	0.77	0.14	0.61	0.061	0.040
7	Virvyčia	Tryškiai	1954	1963	32.1	957.4	1954 – 1963	10.1	10.3	4.68	1.48	1.99	0.42	0.18
8	Rešketa	Gudeliai	1945-07-12 1956-10-04	2000-03-01	0.5	84.2	1946 – 1999	1.04	12.4	0.54	0.21	2.50	0.074	0.036
9	Varduva	Ruzgai	1956	1972	13.4	544.2	1956 – 1972	5.17	10.4	2.68	0.81	1.80	0.40	0.13
10	Bartuva	Skuodas	1945-11-26	-	48.7	616.7	1957 – 2015	7.37	12.3	3.18	0.79	1.29	0.32	0.20
11	Šventoji	Večiai	1957	1966	59.3	35.8	1957 – 1966	0.35	12.0		0.012	0.42	0	0.000
12	Šventoji	Šventoji	2011-10-11	-	7.8	301.9	2013 – 2015							

Table 2. Hydrological parameters of rivers in Venta RBD within Latvian territory

No	River	Monitoring station	Opened	Closed	Distance from the mouth, km	Drainage area km^2	Period of record	Average discharge (Q) m³/s			30-day minimum discharge (Qmin 30) m³/s			Lowest daily discharge for period of observations m³/s
								Multi-year average	Module l/(s·km²)	Q95%	Multi-year average	Module l/(s·km²)	Q 95%	
1	Venta	Kuldīga	17-08-1926	-	82	8320	1927-2015	66.9	8.0	39.6	13.3	1.60	6.08	4.20
2	Bārta	Dūkupji	01-01-1949	-	18	1700	1950–2015	19.9	11.7	12.4	2.33	1.37	0.94	0.28
3	Abava	Renda	16-03-1964	-	32	1830	1965–2015	14.4	7.9	8.28	3.22	1.76	1.36	1.40
4	Irbe	Vičaki	21-08-1945	-	27	1920	1955–2015	16.5	8.6	10.2	4.03	2.10	1.83	0.63
5	Durbe	Cīrava	01-08-1981	-	27	239	1982-2015	4.25	12.9	2.68	0.64	1.96	0.19	0.14
6	Durbe	Dižatupji	05-10-1964	31-12-1980	19	370	1965-1980	3.83	10.36	2.00	0.51	1.39	0.30	0.22
7	Roja	Rojupe	01-11-1979	-	18	398	1980–2015	3.45	8.66	2.22	0.61	1.53	0.20	0.11
8	Užava	Tērande	13-07-1928	-	26	440	1960–1963	4.10	9.33	2.65	1.07	2.43	0.56	0.41
9	Imula	Pilskalne	07-07-1948 05-12-2007	01-03-1995 -	18	207	1949–1994 2009-2015	1.72	8.18	8.83	0.39	1.88	0.15	0.085
10	Ciecere	HPP Pakuļi	01-09-1958 01-01-2008	1987 -	27	352	1960–1987 2008-2015	3.50	8.55	1.81	0.78	1.74	0.57	0.070
11	Rīva	Pieviķi	1945-11-26	-	10	196	1962–2015	2.17	11.1	1.36	0.34	1.72	0.088	0.093
12	Vartāja	Darznieki	21-09-1959 01-01-1975	1971 1995	8.0	450	1960–1970 1975-1994	5.52	12.28	3.23	0.72	1.61	0.32	0.20

Table 3. Hydro-morphological quality of water bodies in Venta RBD within Latvian territory

WB name	WB code	WB type	Substrate	Pressure	HM class
Sventāja	V001	R4	gravel, sand, mud	HPP Lithuanian territory, data lack	3
Ālande	V004	R4	mud	HPP, polders and > 75% of WB' length - water regulations	4
Otaņķe	V005	R3	cobbles, gravel, sand	polders, water regulations	3
Bārta	V006SP	R6	sand, coarse debris, mud	30% of WB length - polders and water regulations	5
Tirdzniecības kanāls (new WB)	V003SP	R6	concrete	AWB, Liepāja seaport	5
Vārtāja	V007SP	R4	boulders, gravel, sand, mud	>75% of WB' length - water regulations, HPP in tributary	5
Vārtāja	V009	R3	mud	2 HPPs	4
Bārta	V010	R6	gravel, sand, coarse debris, mud	HPP Lithuanian territory, data lack	4
Apše	V011	R3	cobbles, gravel, sand	none	1
Bubieris	V012	R1	gravel, sand	none	1
Saka	V013SP	R6	sand, coarse debris, mud	Pavilosta seaport	5
Tebra	V014	R4	sand, mud	morphological changes in riparian zone	2
Alokste	V015	R3	cobbles, gravel, sand	3 HPPs, water regulations	4
Tebra	V018	R3	gravel, sand, mud	1 HPP	3
Durbe	V019	R4	sand, mud	morphological changes, 1 HPP in tributary	2
Durbe	V020	R4	sand, mud	50% of WB' length - water regulations	3
Pažupīte	V022	R1	sand, gravel	none	1
Rīva	V023	R3	cobbles, gravel, sand	none	1
Užava	V025	R4	sand, mud	50% of WB' length - water regulations, polder, 2 HPP in tributary	3
Medoles strauts	V026	R1	gravel, sand	none	1
Venta	V027	R6	sand, coarse debris, mud	morphological changes in riparian zone	2
Packule	V028	R4	gravel, sand, mud	land drainage system (channels)	3
Ventspils seaport territory	V029SP	R6	concrete, sand, mud	15% of WB length - Ventspils seaport, rest - water regulations in tributaries	5
Abava	V032	R6	sand, coarse debris, mud	water regulations and 4 HPPs in tributaries	2

WB name	WB code	WB type	Substrate	Pressure	HM class
Imula	V034	R3	cobbles, gravel, sand	50% of WB' length - water regulations	3
Abava	V038	R4	gravel, sand, mud	>75% of WB' length - water regulations, 1 HPP	4
Viesata	V041	R3	sand, mud	1 HPP	4
Venta	V043	R6	sand, coarse debris, mud	morphological changes in riparian zone, 1 HPP in tributary	2
Riežupe	V044	R3	cobbles, gravel, sand	none	1
Ēda	V046	R3	cobbles, gravel, sand	2 HPPs	4
Venta	V049	R6	sand, coarse debris, mud	Morphological changes in riparian zone, 1 HPP in tributary	2
Lējējupe	V050	R3	cobbles, gravel, sand	50% of WB' length - water regulations, 1 HPP in tributary	3
Ciecere	V054	R3	boulders, cobbles, gravel, mud	3 HPPs	4
Venta	V056	R6	sand, coarse debris, mud	water regulations and 6 HPPs in tributaries	2
Šķervelis	V057	R3	bedrock, boulders, cobbles, gravel	Rukaišu&Dzeldas HPP (in tributaries)	3
Lētīža	V058	R3	boulders, cobbles, gravel	none	1
Zaņa	V060	R3	gravel, mud	Pampāļu&Zaņas HPP	3
Vadakste	V062	R5	boulders, cobbles, gravel, sand, mud	none	1
Ezere	V063	R4	gravel, sand, mud	Grīvaišu&Ezeres HPP (mouth stretch) and water regulations	3
Vadakste	V066	R4	gravel, sand, mud	Vadakstes HPP	3
Lūžupe	V067	R2	sand, mud	none	1
Irbe	V068	R6	coarse debris, sand	none	1
Stende	V069	R6	sand, coarse debris, mud	Dižstendes HPP, >75% of WB' length - water regulations	4
Pāce	V071	R3	boulders, cobbles, gravel, sand	Pāces HPP	3
Raķupe	V072	R3	sand, mud	none	1
Rinda	V075	R4	sand	>75% of WB' length - water regulations	4
Engure	V076	R4	gravel, sand, clay, mud	GravasHPP&Vecdzirnavu HPP	3
Tirukšupe	V078	R4	gravel, sand, mud	>75% of WB' length - water regulations	4

WB name	WB code	WB type	Substrate	Pressure	HM class
Pilsupe	V079	R1	gravel, sand	none	1
Mērsraga kanāls	V080SP	R4	gravel, sand, mud	Mersrags seaport, AWB	5
Roja	V082	R4	cobbles, gravel, sand, mud	25% of WB' length - water regulations	2
Roja	V083	R4	gravel, sand, mud	>75% of WB' length - water regulations	4
Grīva	V084	R3	cobbles, gravel, sand, mud	>75% of WB' length - water regulations	4
Dursupe	V087	R3	sand, mud	Dursupes HPP	3
Dzedrupe	V088	R4	gravel, sand, mud	none	1
Roja ar Mazupīti	V089SP	R4	gravel, sand, mud	7% of WB length - Roja seaport, rest: reference conditions	5
Lāčupīte	V090	R4	sand, mud	Sēmes HPP	3
Slocene	V091	R3	mud	Šlokenbekas HPP& pumping station	4
Slocene	V093	R3	gravel, sand, mud	Morphological changes	2

Table 4. Hydro-technical characteristics of Hydropower Plants in Venta RBD within Lithuanian territory

No	SHP name	River	Distance from the mouth, km	Basin area, km²	Commis-sionning year	Head, m	Reser-voir area, ha	Reservoir normal water level	Installed capacity, kW	Environ-mental flow, m³/s	Turbine flow (min/max), m³/s
1	Užventis	Venta	330.0	45	2004	3.00	16.2	117.00	24	0.020	1
2	Rudikiai	Venta	251.7	1561	2002	2.50	7.7	81.50	70	0.319	0.45//7
3	Žerkščiai	Venta	240	1584	2013				29		
4	Viekšniai	Venta	221.8	3350	2002	3.00	17.0	54.80	95	0.960	-/8.0
5	Jautakiai	Venta	199.0	3690	2005	2.90	25.5	46.50	250	1.360	3.5/13.5
6	Kuodžiai	Venta	188.9	4021	2005	4.50	25.3	44.00	600	1.750	0.5/4.00
7	Sablauskiai	Dabikinė	16.0	276	2007	3.90	125.0	69.00	39	0.054	0.4/0.8
8	Baltininkai	Virvytė	77.7	392	2005	4.30	33.6	143.00	260	0.670	0.5/11
9	Biržuvėnai	Virvytė	72.0	405	2004	3.50	8.66	124.50	200	0.350	0.7/6.0
10	Juciai	Virvytė	65.2	420	2002	3.40	25.4	117.80	100	0.310	-/4.0
11	Tryškiai	Virvytė	32.1	957	2010				90		
12	Sukončiai	Virvytė	29.8	960	1997	4.40	10.0	88.10	320	0.620	2.0/8.0
13	Balsiai	Virvytė	27.7	965	2002	3.30	11.6	83.65	202	0.630	1.0/6.0
14	Rakiškė	Virvytė	23.1	980	1999	4.00	8.7	79.90	230	0.640	-/10
15	Kairiškiai	Virvytė	20.2	982	2001	3.20	7.6	76.20	160	0.660	2.7/5.0
16	Kapėnai	Virvytė	13.4	1056	2005	5.50	13.6	69.30	288	0.680	3.0/9.0
17	Skleipiai	Virvytė	10.8	1122	1999	3.70	8.0	64.70	230	0.680	2.0/4.6
18	Gudai	Virvytė	6.6	1125	2002	3.30	7.9	60.92	230	0.89	1.0/6.0
19	Ubiškė	Patekla	5.1	339	1997	10.00	73.0	73.00	350	0.310	3.46
20	Šerkšnėnai	Šerkšnė	23.8	215	1997	4.60	16.8	80.00	64	0.140	0.34/2.06
21	Leckava	Ašva	0.6	157	2003	7.00	11.7	50.00	125	0.031	0.5/3.0
22	Kulšėnai	Varduva	58.0	335	1998	3.40	2.2	105.25	115	0.200	0.5/6.0
23	Renavas	Varduva	44.2	357	1995	8.90	29.1	88.90	300	0.370	2.4/9.0
24	Vadagiai	Varduva	37.1	367	2004	3.50	5.6	78.00	110	0.410	1.2/5.7
25	Ukrinai	Varduva	27.6	378	2002	3.30	9.6	65.00	110	0.460	0.5/6.0
26	Juodeikiai	Varduva	6.7	579	1996	12.50	261.4	58.00	820	0.910	3.5/8.0
27	Alsėdžiai	Sruoja	27.6	69	2004	4.20	2.3	136.10	75	0.091	0.5/1.9
28	Puodkaliai	Bartuva	62.4	129	2005	5.20	8.0	28.50	80	0.070	0.3/4.0

No	SHP name	River	Distance from the mouth, km	Basin area, km²	Commis-sionning year	Head, m	Reser-voir area, ha	Reservoir normal water level	Installed capacity, kW	Environ-mental flow, m³/s	Turbine flow (min/max), m³/s
29	Skuodas	Bartuva	55.0	258	2000	8.00	85.9	23.70	220	0.220	0.4/3.0
30	Kernai	Erla	0.5	111	2005	7.90	76.7	31.40	110	0.090	0.5/2.4

Table 5. Hydro-technical characteristics of Hydropower Plants in Venta RBD within Latvian territory

River	HPP	Distance from river mouth, km	Authority	WB code	Commissioning year	Turbine type*	Installed capacity, kW	Q, m^3/s	Reservoir area, km^2	Head, m
Ālande	Grobiņas	8.0	Grobiņa	V004	2001	1K+1F	70	0.018	0.092	4.2
Birztala	Dižgramzdas	12.0	Gramzda	V007SP	2001	No	18.5	0.022	0.067	3.4
Virga	Prūšu	4.0	Virga	V007	2002	2K	200	0.041	0.68	12
Vārtaja	Bunkas	33.0	Bunka	V009	1999	1F	75	0.076	0.25	4.5
Vārtaja	Krotes	52.0	Bunka	V009	2002	2K	90	0.045	0.145	5.2
Alokste	Apriķu	7.5	Laža	V015	1999	1F+2K	230	0.16	0.59	6.3
Alokste	Baronu	1.8	Laža	V015	2001	4K	410	0.17	0.31	5.5
Alokste	Kazdangas	31.0	Kazdanga	V015	2002	2F+1K	200	0.16	0.24	5.1
Tebra	Aizputes	30.0	Aizpute	V018	1996	2F (horizont.)	60	0.060	0.058	3.7
Cepļupe	Cīravas	0.1	Cīrava	V019	2002	1F	65	0.050	0.068	4.5
Kaliņa	Alsungas	3.0	Alsunga	V025	1999	2F	110	0.083	0.090	5.7
Vanka	Ēdoles	12.0	Ēdole	V025	1999	2F (horizont.)	48	0.058	0.073	5.5
Īvande	Rendas	1.7	Renda	V032	2002	2K	20	0.080	0.017	3.6
Virbupe	Dzelzāmuru	9.0	Virbi	V032	2002	1K	55	0.009	0.062	5.8
Virbupe	Sendzirnavas	6.8	Sabile	V032	1998	1F	75	0.15	0.15	5.0
Dzirnavupīte	Strazdes	1.5	Strazde	V032	2009	-	18	-	-	-
Abava	Bišpēteru	114	Irlava	V038	2002	2K	100	0.60	0.11	2.2
Viesate	Viesatu	23.0	Viesāti	V041	1999	2F	60	0.037	0.090	6.1
Padure	Padures	4.0	Padure	V043	2002	2F (horizont.)	85	0.017	0.18	5.7
Šķēde	Spīķu	14.0	Šķēde	V046	1997	1F+1K	140	0.080	0.26	6.3
Šķēde	Šķēdes	9.0	Vārme	V046	1999	1F+1K	97	0.080	0.16	5.9
Ēnava	Sudmalnieku	0.1	Raņķi	V049	1999	2K	30	0.029	7.5	2.5
Lējējupe	Mazsālijas	8.7	Snēpele	V050	1998	No	-	-	-	-
Ciecere	Cieceres	49.0	Brocēni	V054	1996	2K	150	0.061	0.077	4.0
Ciecere	Pakuļu	28.0	Zirņi	V054	1996	2K	250	0.32	1.61	7.8

River	HPP	Distance from river mouth, km	Authority	WB code	Commissioning year	Turbine type*	Installed capacity, kW	Q, m^3/s	Reservoir area, km^2	Head, m
Bērzkrogs	Urbuļu	0.4	Nīkrāce	V056	2012	Propeller type	20	0.03	0.038	-
Ciecere	Dzirnavnieku	32.0	Saldus	V054	1999	2K	116	0.30	0.079	4.0
Imala	Lēnu	0.6	Nīkrāce	V056	2010	Propeller type	22.5	0.015	0.022	-
Koja	Rudbāržu	6.5	Rudbārži	V056	1999	2F (horizont.)	94	0.014	0.057	5.2
Loša	Grantiņu	6.0	Kalna	V056	1998	1F+1K	128	0.20	0.003	3.6
Loša	Lejnieku	1.0	Kalna	V056	1998	2K	100	0.043	0.155	6.0
Skutulis	Griezes	0.5	Nīgrande	V056	1998	1F	25	0.025	0.011	6.2
Dzelda	Dzeldas	11.0	Nīkrāce	V057	2000	2K	125	0.040	0.31	5.0
Šķērvele	Rukaišu	1.0	Nīkrāce	V057	2001	1F	25	0.030	0.29	4.6
Zaņa	Pampāļu	21.5	Pampāļi	V060	2000	2K	100	0.20	0.20	4.6
Zaņa	Zaņas	8.5	Zaņa	V060	1999	2K	225	0.069	0.26	5.0
Ezere	Ezeres	0.3	Ezere	V063	2001	1K	67	0.084	0.175	3.7
Ezere	Grīvaišu	5.0	Ezere	V063	2001	3K	400	0.30	0.30	6.0
Vadakste	Vadakstes	48.0	Vadakstes	V066	2001	2K	200	0.050	1.00	5.5
Stende	Dižstendes	93.0	Lībagi	V069	2001	1F	30	0.030	0.105	4.0
Pāce	Pāces	9.0	Dundaga	V071	2001	1K	110	0.036	0.021	5.0
Engure	Gravas	18.0	Ugāle	V076	2001	2K	145	0.77	0.082	3.0
Engure	Vecdzirnavu	15.0	Ugāle	V076	2001	1F	55	0.77	0.082	3.0
Kāņupe	Mordangas	8.5	Ģibuļi	V077	2001	1F	80	0.052	0.016	3.8
Kalnupe	Rideļu	5.5	Engure	V086	1997	1F	30	0.010	0.36	5.0
Dursupe	Dursupes	20.0	Balgale	V087	1998	1F	22	0.055	0.062	4.2
Lāčupe	Sēmes	20.0	Sēme	V090	2002	2K	10	0.050	0.041	5.0
Slocene	Šlokenbekas	22.0	Smārde	V091	2001	2F	43	0.030	0.095	6.0

**Turbine types: F-Frensis, K-Kaplan, M-Mavel*

ANNEX II

Description of Lithuanian Fish Index (LFI)

Method is developed for < 6 m/km slope, ~> 20 km² catchment size, permanently flowing rivers, with natural fish communities consisting of at least 3 species. It covers 6-8 metrics, depending on river type. The metrics are calculated based on single run electric fishing, performed in river stretches 10 times longer than wetted width. To calculate the index, rivers should be grouped in types based on catchment size and slope of riverbed (Table 1).

Table 11. Physiographic variables representing river types (CS – catchment size, km²; SLO – gradient slope, m/km).

Variables	**River types**				
	1	**2**	**3**	**4**	**5**
CS	<100	100-1000		>1000	
SLO	-	<0.7	≥0.7	<0.3	≥0.3

The list and description of metrics, as well as reference values for different river types are presented in Table 2.

Table 2. The list of metrics and reference values for different river types.

Metrics	**Description**	**River types**				
		1	**2**	**3**	**4**	**5**
INTOL_ n %	percentage of individuals of intolerant species from the total number of individuals	6 1	22	45	18	27
INTOL_sp_Nb	number of intolerant species	3		5		5
LITH_ n %	percentage of individuals of litophilic species from the total number of individuals	9 6	52	93	33	65
LITH_ sp_Nb %	percentage of number of litophilic species from the total number of species	8 3	41	72	39	52
TOLE_ n %	percentage of individuals of tolerant species from the total number of individuals	1	33	2	37	23
TOLE_sp_Nb %	percentage of number of tolerant species from the total number of species		18	14	18	14
RH_sp_Nb	number of rheophilic species		5	8	6	10
OMNI_n %	percentage of individuals of omnivorous species from the total number of individuals	3	37	4	53	38

To calculate the index, metrics values should be transformed to ecological quality ratios (EQR) as follows:

- for metrics, decreasing with degradation (INTOL, LITH and RH guilds):

$$EQR = R/RC$$

- for metrics, increasing with degradation (TOLE and OMNI guilds):

$$EQR = (R - 100)/(RC - 100)$$

R – measured value;
RC – reference value (given in Table).

LFI is an average of EQR‘s of all metrics. If the EQR of the metric is greater than “1”, it has to be equated to "1“, before calculating LFI (average of EQR‘s).
Method classifies ecological status by one of five classes (high, good, moderate, poor and bad). The range of LFI values per status class is given in Table 3.

Table 3. The range of LFI values per status class.

River types	Status				
	High	**Good**	**Moderate**	**Poor**	**Bad**
All types	> 0.94	0.94-0.72	0.71-0.40	0.39-0.11	< 0.11

Description of Lithuanian River Macroinvertebrate Index (LRMI)

Multihabitat sampling should be used: 10 pooled subsamples proportionally distributed across the habitats available at a site. Each subsample collected using the kick method by holding a standard handnet (25 x 25 cm, 0.5 mm mesh size) perpendicular to the bottom of river against the current and by disturbing the 40 cm length area in front of it, resulting in 0.1 m^2 of bottom area per subsample and 1 m^2 of bottom area in total for the main sample. Additional qualitative samples collected by searching for macroinvertebrates attached to underwater objects (roots, stones, plants, etc.). The taxa found in qualitative samples added to the taxa lists with quantity of 1 individual if not discovered in the main sample.
Macroinvertebrate identification levels for the calculation of LRMI are provided in Table 1. Most groups are identified to species level, with the exceptions of Oligochaeta, Coleoptera and Diptera. Hydracarina and Aranea are not considered as well.

Table 1. Macroinvertebrate groups considered in LRMI with their identification levels and excluded families.

Macroinvertebrate group	Identification level	Excluded families
Turbellaria	Species	
Oligochaeta	Class	
Hirudinea	Species	
Mollusca	Species	Succineidae, Zonitidae
Crustacea	Species	
Plecoptera	Species	
Ephemeroptera	Species	
Odonata	Species	
Heteroptera	Species	Gerridae, Hydrometridae, Mesoveliidae, Veliidae
Megaloptera	Species	
Neuroptera	Species	
Coleoptera	Genus	Chrysomelidae, Curculionidae
Trichoptera	Species	
Lepidoptera	Species	
Diptera	Family	

LRMI has the strength of four submetrics. Using reference and lower anchor values (Table 2), each submetric is first standardised using formula:

$$\mathrm{EQR} = \frac{\text{Observed value} - \text{Lower anchor}}{\text{Reference value} - \text{Lower anchor}}.$$

LRMI is calculated by averaging all four standardized submetrics. Occasionally the sample cannot be classified using DSFI; in this case DSFI is excluded from the average.

Table 2. Description of LRMI submetrics and their reference values.

Abbreviation	Description	Reference value	Lower anchor
DSFI	Danish Stream Fauna Index (Skriver et al. 2001)*	7	1
ASPT	Average Score Per Taxon of original BMWP system (Armitage et al. 1983)**	7.0	1.0
#DEP	Total number of taxa of Diptera (families), Ephemeroptera and Plecoptera (species)	15	0
%EHP–%CrHi	Difference between total share of Ephemeroptera, Hemiptera and Plecoptera individuals and total share of Crustacea and Hirudinea individuals	0.6	–1.0

* Skriver J, Friberg N, Kirkegaard J (2001) Biological assessment of running waters in Denmark: introduction of the Danish Stream Fauna Index (DSFI). Verhandlungen der Int Vereinigung für Theor und Angew Limnol 27:1822–1830.
** Armitage PD, Moss D, Wright JF, Furse MT (1983) The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Res 17:333–347.

Class boundaries for the LRMI are given in Table 3.

Table 3. Class boundaries for the LRMI method.

Class boundary	**High / Good**	**Good / Moderate**	**Moderate / Poor**	**Poor / Bad**
LRMI	0.73	0.62	0.56	0.39

Description of River Hydromorphological Index (RHI)

RHI is the sum of scores of four metrics, described in Table 1.

Table 1. Description of hydromorphological quality metrics, covered by RHI.

Element	Metric	Spatial scale	Description	Score
Hydrological regime	Water quantity and dynamics	site	No changes in water quantity due to human activities (water abstraction, HPP functioning, water discharge from ponds, impoundment), or changes are insignificant (≤10 % of average water quantity and flow pattern at certain period of the year); however, water quantity should not be less than minimum natural discharge during dry period (average of 30 days).	1
			Changes in natural water flow due to water abstraction, retention or discharge reach up to 10-30%	3
			Changes in natural water flow are due to HPP functioning (non-peak regime); or the current is slowed down due to the impact of impoundment downstream the site.	4
			Changes in natural water flow are due to HPP hydropeaking; or changes in natural water flow (water abstraction or discharge) are >30%; or current is stopped and water level is risen due to impoundment.	5
Morphological conditions	Status of river bed	segment *	Riverbed is natural (not straightening, no embankment, no deepening)	1
			Riverbed is regulated. The shore line is not embanked, meandrous (variation in channel width ≥25%); or shore line is modified by dikes. Depth in longitudinal profile varies significantly (rapids and pools are present).	3
			Riverbed is regulated. The shore line is not embanked, or embankment covers < 50% of the segment; the shore line is meandrous (variation in channel width ≥25%), but there is no variation in channel depth.	4
			Riverbed is regulated and embanked (> 50%) and / or maintained (the shore line is straight, no variation in depth).	5
	Status of riparian vegetation	segment *	The belt of natural riparian vegetation covers at least 70 % of the shore zone on both sides of the river, the width of riparian belt is at least 50 meters; or one river bank is covered by > 50 m width natural vegetation and another bank is covered by rarefied woody vegetation.	1
			Natural riparian vegetation is present only on the one river bank, while on the other bank the riparian belt is narrow or absent; or narrow belts of riparian vegetation are present on the both river banks.	2
			The narrow belt of riparian vegetation is present only on the one river bank, while another bank of the river is covered by solitary trees or woody vegetation is absent; or solitary trees are present on both banks of the river.	3
			Natural riparian vegetation is destroyed: both banks of the river are covered by bushes, or woody vegetation is absent at all.	5
	Bottom substrate composition	segment **	Bottom substrate is heterogeneous, consists of solid particles of various grain size (sand and gravel and/or pebble and/or cobble and/or stones)	1
			Bottom substrate is dominated by homogenous fine-grained particles (sand and/or clay)	2
			silt covers 25-50% of the riverbed	+1
			silt covers 50-90% of the riverbed (small isles of clear bottom are still present)	+2
			Riverbed is covered by silt (>90% of bottom area)	5

* – < 100 km^2 catchment size rivers – 0,5 km above and 0,5 km below the sampling site; 100–1000 km^2 catchment size rivers – 2,5 km above and 2,5 km below; >1000 km^2 catchment size rivers – 5 km above and 5 km below the sampling site.

** - < 100 km^2 catchment size rivers – 50 m above and 50 m below the sampling site; 100–1000 km^2 catchment size rivers – 100 m above and 100 m below; >1000 km^2 catchment size rivers – 200 m above and 200 m below the sampling site.

RHI is transformed to 1-0 scale according to the following formula:

RHI = (maximum sum of the scores – calculated sum of the scores) / (maximum sum of the scores –minimum sum of the scores)
Where: maximum sum of the scores = 20, minimum sum of the scores = 4.

Class boundaries for the RHI are:

	High	**Good**	**Moderate**	**Poor-Bad**
RHI	>0.90	0.90-0.80	0.79-0.50	<0.50